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ACRONYM LIST

Acronym	Explanation
ac or Ac	Acre(s)
CEQ	Council on Environmental Quality
CPOM	Coarse Particulate Organic Matter
DEM	Digital Elevation Model
DOM	Dissolved Organic Matter
DOC	Dissolved Organic Carbon
FPOM	Fine Particulate Organic Matter
GIS	Geographic Information System
Mi	Miles
MMU	Minimum Mapping Unit
MTM/VF	Mountaintop Mining/Valley Fill
NEPA	National Environmental Policy Act
NLCD	National Land Cover Datasets
NDVI	Normalized Difference Vegetation Index
NRAC	Natural Resource Analysis Center
NRAV	Natural Resource Analysis Center (of WVU)
PEC	Potential Ecological Condition
WVGAP	West Virginia Gap Analysis Project

EXECUTIVE SUMMARY

This Landscape Scale Cumulative Impact Study evaluates the potentially adverse impacts of future mountaintop mining in a four-state study area in the Mid-Atlantic Region of the United States. The study area encompasses 12,200,888 acres within the Appalachian Coalfield Region in portions of West Virginia, Virginia, Tennessee, and Kentucky. The study area is characterized by steep mountainous slopes, confined river valleys, and narrow ridge tops. Forests dominate the land cover of the study area covering11,231,622 acres (92.1%). Ecological communities of the study area are unique in that they combine characteristically northern species with their southern counterparts, and thus boast great richness and diversity.

The potential adverse impacts of mountaintop mining in the study area are evaluated here at both a state-by-state level and the four-state study area level. Potential adverse impacts to aquatic, terrestrial, and riparian habitats are assessed. In addition, the West Virginia portion of the study area is evaluated in further detail as described below.

The study uses a Geographic Information System (GIS) approach to project future potentially adverse impacts on the natural environment within the study area by measuring specific landscape indicators. Aquatic, terrestrial, and riparian habitat data were acquired and entered into the GIS to determine pre-impact conditions of the study area. Then surface mine and valley fill spatial coverages from issued mine permits were imported into the GIS to calculate projected potentially adverse impacts. Within the West Virginia portion of the study area the GIS was used to calculate more detailed landscape indicators, some at the watershed level. The study methods build upon a Landscape Assessment Approach developed by Canaan Valley Institute and "landscape indicators" used to assess watershed conditions as described in the publication An Ecological Assessment of the United States Mid-Atlantic Region: A Landscape Atlas USEPA Office of Research and Development, Washington DC, November 1997.

Future ecological conditions in the study area are represented by the results of the landscape indicators. Landscape indicators are specific metrics (calculations) that provide an index to the

health of an ecological region. Landscape indicators are direct or indirect measures of environmental parameters or combinations of parameters. By evaluating several indicators for a specific landscape unit (study area) it is possible to assess a level of ecological integrity or vulnerability to degradation.

Landscape indicator metrics calculated for each state and the four-state study area include:

- Mine permit surface area (ac)
- Direct impact to streams (mi and %)
- Direct impact to forests (ac and %)
- Grassland as indicator of past mining impact (ac and %)
- Non-forest land cover class area change (ac and %)

Landscape indicator metrics calculated in further detail for the West Virginia portion of the study area include:

- Mine data ratios (ac) - Valley fill area to mineral extraction area, Valley fill area to permit area, Mineral extraction area to permit area
- Direct impact to streams from valley fill area (mi and %)
- Direct impact to streams from mineral extraction area (mi and %)
- Direct impact to streams from permit area (mi and %)
- Forest loss from permit area (ac and %)
- Forest loss from valley fill area (ac and %)
- Forest loss from mineral extraction area (ac and %)
- Forest loss from auxiliary areas (ac and %)
- Impacts to riparian habitats (ac)
- Potential Ecological Condition (unit)
- Forest edge (%)
- Number of land cover patches (count)
- Percent landscape of patch type (%)
- Mean patch size (ac)

All metrics and the input data utilized are described in detail within the methodology section of the report. Individual metrics may not describe the complete ecological condition of a watershed. However, when considered collectively some conclusions regarding the ecological health of the watershed may be reached.

Mountaintop Mining Surface Area Metric Results

In the last ten years 403,810 acres were permitted for surface mining in the study area. Disturbance from surface mining has ecological implications in that the conversion of land use leads to a change in available habitat.

Aquatic Metric Results

The stream network used in the study is a synthetic network generated from a Digital Elevation Model (DEM). A DEM is a digital representation of the earth's surface based on a regular series of sample elevation points. The detail of a synthetic stream network generated in this fashion exceeds that of a USGS 1:24000 scale stream network. There are 58,998 miles of stream in the study area, as calculated by the synthetic network. The Kentucky portion of the study area contains more than one-half of the total stream lengths with 34,468 miles. Studies conducted in the West Virginia portion of the study area, which has over 12,000 miles of streams, indicate that first and second order streams comprise more than one-half of the total stream length in the study area.

Mountaintop mining has the potential to adversely impact 1,208 miles of stream in the study area (2.05%). The potential adverse impact to streams within the Kentucky portion of the study area is 730 miles, or 2.12%. While the greatest potential adverse impact in terms of percent of streams loss is in the West Virginia portion of the study area at 2.55%, or 307 miles.

Direct impacts to streams in the study area were calculated by mineral extraction area (0.42%) and valley fill (1.31%) that would result in actual destruction of existing streams. Indirect impacts to streams such as those that would occur downstream from filled or mined out stream areas were not evaluated in this analysis. As such, results of the direct impacts of stream metrics likely underestimates total impacts to streams.

Terrestrial Metric Results

Forests dominate the terrestrial habitats of the study area. Dominant among these forest types is the diverse mesophytic hardwood forest. This forest type is characterized by a diverse understory of trees that never attain canopy status and wildflowers are common. The cove hardwoods are a type of mixed mesophytic hardwood forest. Cove hardwoods are found in ravines, coves and along north-facing slopes. Due to the abundance and variety of fruits, seeds, and nuts the diverse mesophytic forest type provides excellent habitat for wildlife and game species alike. Grasslands and open habitats are naturally rare in the study area, therefore, species that require these types of habitats are also, generally rare in the study area.

Forest loss has the potential to impact the biodiversity of the study area in the form a floral and faunal shift with grassland species becoming more common. Likewise increases in edge habitat and forest fragmentation may lead to an increase in the number and abundance of edge dwelling species while inflicting a cost on forest interior species. Forest interior species, such as neotropical migrant birds, and terrestrial salamanders may be significantly impacted by such land use changes due largely to direct loss of critical habitat. The study area contains critical habitat for many forest interior bird species, likewise, forests in the eastern United States are among the most diverse in salamander richness and abundance in the world.

A decrease in forest cover, subsequently followed by conversion to grasslands, within the study area has the potential of shifting the fauna of the region from that which is dependent upon undisturbed intact forest to one dominated by grassland and edge dwelling species. This shift may take a considerably long amount of time to be recognized; however, some changes may be recognized immediately. This is a potentially adverse change in that many of the species that may be replaced have ranges that are restricted to the study area and nearby similar habitats. Thus, a change in these habitats could put a number of species in peril. The shift in terrestrial habitat would provide new refuge for some species that are considered rare in the study area, however, most of these species are well established in other parts of their range and are most likely rare in West Virginia because their habitat does not naturally occur there.

Results of this study support the thesis that fundamental changes to the terrestrial environment of the study area may occur from mountaintop mining. For example, it is estimated that the study area may have lost approximately 3.4% forest cover in the last ten years from surface mining. This equates to 380,547 acres. When adding past, present and future terrestrial disturbance, the study area estimated forest impact is 1,408,372 acres which equates to 11.5 % of the study area. This number is derived by adding grassland as an indicator of past mining, barren land classification, forest lost from the last ten years of surface mine permits and a projection of future forest loss that equates to the last ten years.

Much of this forest is the predominant diverse mesophytic hardwood forest, however, impacts to cove hardwood, oak, and other forest types are also expected. The predicted condition from the permit data suggests more than a 3X increase in the surface mining/quarries/gravel pits land class to 334,791 acres, and this is an underestimation because only fours years of permit data were used for the Kentucky evaluation of this metric . Not projected by the data but intuitively expected is a similar increase in the grassland cover types in the study area as mine sites move into reclamation. Furthermore, the permit data predict that edge habitat will increase by as much as 2.7% from the present condition in the West Virginia portion of the study area. Fragmentation of the terrestrial environment, predicted in the West Virginia portion of the study area, will be recognized by an increase in the number of land use patches from the present 100,392 to 139,689 and a decrease in average patch size under the permit condition.

All of these changes suggest that the biological integrity of the study area may be jeopardized. The potential ecological condition (PEC) is a measure of the biological integrity specific for eastern forests that takes into account forest cover, interior forest, and surrounding land use. PEC was calculated at the watershed level for the West Virginia portion of the study area and graphically extrapolated to predict PEC of the four-state study area. Results suggest that the predicted pre-impact PEC of study area is higher than that of the issued permits condition.

Riparian Habitat Metric Results

Riparian habitats are generally ecologically diverse and they often provide habitat for unique, or ecologically important species. For example, many neotropical migrant birds utilize this habitat type for breeding and the moist environment provides excellent habitat for salamanders. Furthermore, riparian habitats are the interface between the terrestrial and aquatic environment thus they contribute to the flow of energy between these environments. Due to the rugged topography of the study area, a large majority of the riparian habitats are associated with small, first and second order, streams.

Riparian habitats occupy 236,843 acres of the West Virginia portion of the study area. The projected potential adverse impacts in the West Virginia portion of the study area is 7,591 acres, or 3.2%. Approximately 55% of the projected riparian habitat impacts occur in first and second order streams which are important habitats to many species of salamanders and other wildlife.

I. INTRODUCTION

This Landscape Scale Cumulative Impact Study evaluates the cumulative impacts of past, present, and proposed mountaintop mining in a four-state study area of the Mid-Atlantic Region of the United States. The term mountaintop mining as used in this study refers to all surface mining in steep slope Appalachia. This study evaluates all surface mining operations in the study area that were permitted in or after 1992. Excluded from the study are permits that represent underground mining, preparation facilities, coal waste disposal areas, etc. so that only past, present, and projected surface mining activities are included. It is assumed that disturbances for permits approved before 1992 that were still operating after 1992 will be offset by digitized permits approved in recent years (2000-2002) that have not commenced.

A detailed description of the study methods is included in Section II - Methodology. In short the study evaluated impacts to both the aquatic and terrestrial environment in the four-state study area using digitized permit polygons and land cover data imported into a geographic information system (GIS).

In an attempt to relate the project impacts to cumulative impacts in the natural environment the study further evaluated a portion of the study area (West Virginia) in greater detail using methods built upon a Landscape Assessment Approach developed by Canaan Valley Institute and "landscape indicators" used to assess watershed conditions as described in the publication *An Ecological Assessment of the United States Mid-Atlantic Region: A Landscape Atlas* USEPA Office of Research and Development, Washington DC, November 1997. The detailed West Virginia-based study evaluated the future impacts based on permit data that was 60% complete.

Future ecological conditions in the study area are represented by the results of the landscape indicators. Landscape indicators are specific metrics that provide an index to the health of an ecological region. Landscape indicators are direct or indirect measures of environmental parameters or combinations of parameters. By evaluating several indicators it is possible to assess a level of ecological integrity or vulnerability to degradation relative to other watersheds.

All metrics and the input data utilized are described in detail within the methodology section of the report. Individual metrics may not describe the complete ecological condition of a watershed; however, when considered collectively some conclusions regarding the ecological health of the watershed may be reached.

The report begins with a brief description of aquatic and terrestrial habitats. Factors such as forest fragmentation are discussed as they relate to the study area habitats. Section II of the report details the study methodology including a description of the metrics and the geographic data sets. Section III presents the landscape indicator metric results including tables, figures and graphs. Section IV presents a discussion of the ecological significance of the landscape indicator metric results.

A. STUDY AREA

The study area includes eastern Kentucky, northwest Virginia, southwestern West Virginia and a small portion of Tennessee (Figure I.A-1). It covers an area of 12,200,888 acres. The study area is located within portions of nine ecological subregion sections (refer to Figure I.A-1).

Analysis at the ecological subregion level is of considerable value when the purpose is for strategic, multi-forest, statewide, and multi-agency assessment because several variables are considered when defining the boundaries of each ecological subregion (U.S. Forest Service, USDA, 2002). The ecological units of an ecological subregion analysis are termed *sections*. Within an ecological subregion section geomorphology, lithology, soils, vegetation, fauna, climate, surface water characteristics, disturbance regimes, land use, and cultural ecology are generally similar.

The percent of each ecological subregion section in the study area is outlined in Table I.A-1. Nearly 90% of the North Cumberland Mountains Ecological Subregion lies within the study area.

Characteristics of each ecological subregion section of the study area are summarized in Table I.A-2.

Table I.A-1

Ecological Subregion Section in the Study Area

Ecological Subregion	**Percent in Study Area (%)**
Allegheny Mountains	6.5
Central Ridge and Valley	0.4
Interior Low Plateau, Bluegrass	0.4
Interior Low Plateau, Highland Rim	0.7
Northern Cumberland Mountains	89.7
Northern Cumberland Plateau	57.9
Northern Ridge and Valley	0.9
Southern Cumberland Mountains	49.2
Southern Unglaciated Allegheny Plateau	11.0

Source: U.S. Forest Service, USDA, 2002

Table I.A-2

Ecological Subregion Section Characteristics

Ecological Subregion	**Geomorphology (Province)**	**Natural Vegetation (Forest Type)**	**Climate (mean annual)**
Allegheny Mountains	Appalachian Plateaus	Northeastern Spruce-Fir Northern Hardwoods Mixed Mesophytic Oak-Hickory-Pine	Prec: 46-60" Temp: 39-54°F
Central Ridge and Valley	Ridge and Valley	Appalachian Oak	Prec: 36-55" Temp: 55-61 °F
Interior Low Plateau, Bluegrass	Interior Low Plateaus	Oak-Hickory	Prec: 44" Temp: 55 °F
Interior Low Plateau, Highland Rim	Interior Low Plateaus	Oak-Hickory	Prec: 44-54" Temp: 55-61 °F
Northern Cumberland Mountains	Appalachian Plateaus	Mixed Mesophytic Appalachian Oak Northern Hardwoods	Prec: 40-47" Temp: 45-50 °F
Northern Cumberland Plateau	Appalachian Plateaus	Mixed Mesophytic Appalachian Oak	Prec: 46" Temp: 55 °F
Northern Ridge and Valley	Ridge and Valley	Appalachian Oak Oak-Hickory-Pine Northern Hardwoods	Prec: 30-45" Temp: 39-57 °F
Southern Cumberland Mountains	Appalachian Plateaus	Appalachian Oak Mixed Mesophytic	Prec: 46" Temp: 55 °F
Southern Unglaciated Allegheny Plateau	Appalachian Plateaus	Mixed Mesophytic Appalachian Oak	Prec: 35-45" Temp: 5

Source: U.S. Forest Service, USDA, 2002

The study area is located within the Appalachian Coalfield Region of the Appalachian Plateau physiographic province and Bituminous Coal Basin. The rugged terrain of this region is generally characterized by steep mountain slopes, confined river valleys, and narrow ridge tops. The geologic processes and climatic conditions responsible for the formation of these land forms, have as a result, helped to determine the past and present land use and land cover of the region. The ecological communities of the study area are unique because they combine characteristically northern species with their southern counterparts, and thus boast enormous richness and diversity.

B. AQUATIC HABITATS

Lotic or flowing aquatic systems are important landscape features in the study area. Lotic systems may be considered to include rivers, streams, and creeks and springs. This section will discuss the types, features and functions of lotic systems in the study area.

1. Representative Streams

a. Physical Characteristics

Numerous physical parameters such as flow volume, substrate (i.e., the stream bottom made up of cobbles, gravel, sand, etc.), water chemistry, and bank cover influence the biota of the aquatic systems in the study area. These parameters are determined by the climate, lithology, relief and land use in the area of a particular stretch of stream.

b. Stream Classification

Streams are generally classified through a system called stream ordering (Strahler, 1957). This system classifies streams based on size and position within the drainage network. A first-order stream is defined as not having tributaries. The confluence of two streams of the same order produces the next highest order. For example, the joining of two first-order streams results in a second-order stream. The joining of two second-order streams produces a third-order stream, etc. Headwaters are usually classified as first- through third-order streams, mid-sized streams as fourth- through sixth-order streams, and larger rivers as seventh- through twelfth-order streams (Ward, 1992).

c. Habitats in Streams

Generally, headwater streams originate at high elevations in the study area. Substrate patterns in headwater streams channels are typically comprised of coarser material such as boulders, cobble rubble and bedrock. Large, woody debris often contribute to the substrate complexity in headwater streams. Small pools with finer sediments may also be found along headwater streams. Typical substrate patterns in larger rivers are comprised of finer material such as silt and sand. Mid-sized rivers typically contain a blend of cobble and gravel with some finer sediment interspersed in areas of slower flow.

The combination of substrate characteristics and varying flow rates and other flow characteristics (hydrologic cycles, flow patterns, load transport and storage) produce channel features such as riffles, runs, and pools. Riffles are erosional habitats where surface water flows over coarser substrate, creating turbulence, which causes disturbances in the surface of the water. This turbulence increases levels of dissolved oxygen by encouraging the mixing of oxygen in the air with the water. Pools are depositional areas where flow is slow or stagnant, allowing finer particulate matter to settle onto the stream bottom. Runs are moderately fast sections of streams where the water surface is not as disturbed. Headwater streams, typically consist of alternating riffles and runs though small depositional pools, may be present and represent an important microhabitat. Mid-sized rivers typically contain all three features because increased width and depth allow more variation in flow.

Stream features that are important in determining habitat for aquatic organisms include, overhanging vegetation, the presence and characteristics of leaf packs, in-stream vegetation, large woody debris, undercut banks, and exposed tree roots. Overhanging vegetation consists of riparian shrub and herbaceous vegetation on banks that grows over and sometimes into the surface water. In-stream vegetation occurs where proper substrate and flow conditions allow growth. Snags are pieces of wood that have accumulated in a stream area. Undercut banks and exposed tree roots are caused by a combination of unstable banks and fast streamflow. All of these features provide unique habitat for cover, habitat, and food for macroinvertebrates and fish.

Other in-stream features that provide additional habitat include littoral areas such as shorelines, sandbars, and islands. Typically these features exist most prominently in depositional systems such as larger rivers. These littoral areas are shallow habitats, which provide habitat for smaller fish and macroinvertebrates that are unable to live in the deeper sections of the river.

2. Energy Sources and Plant Communities

Aquatic ecosystem energy sources consist of allochthonous (material produced outside the stream such as leaves, wood, etc.) and autochthonous (instream primary production by plants, algae) sources. Allochthonous organic material includes leaves and woody material. These materials reach the stream either through directly falling into the stream or through indirectly being transported into the stream, commonly though wind movement or runoff. Allochthonous organic material has been found to be the predominant energy source in high-gradient streams of the southern Appalachians (e.g., Hornick et al., 1981, Webster et al., 1983, Wallace et al., 1992). Headwater energy sources are utilized, not only by invertebrates and vertebrates in upper reaches of the watershed, but, excess organic carbon is subsequently utilized by life forms in all stream orders down gradient. Since streams have a unidirectional flow, downstream areas are also dependent on upstream areas for portions of their energy (Vannote et al. 1980).

Plant communities of high-gradient streams live in what may be considered to be a physically challenging environment. Frequently these habitats are densely shaded and subject to high current velocities. As a result, the plant communities in high-gradient streams are reduced relative to lentic habitats and low-gradient streams (Wallace et al., 1992). However, the plant communities occurring in high-gradient streams contain flora uniquely adapted to survive in this type of environment. This habitat also supports an abundance of flora considered to be endemic (i.e., not found in other locations) to the region (Patrick, 1948). Possibly, the historic lack of direct anthropogenic (human-induced) disturbance to watersheds of high-gradient streams may have contributed to the survival of the unique and endemic flora of this region (Wilcove et al., 1998).

a. Primary Producers and Primary Production

Primary production is the input of energy into a system by the growth of flora living in the system. In streams, primary production is generally measured as mass of carbon or ash free dry mass, which is largely carbon, per unit area, per year. Primary production rates in Appalachian streams have been shown to vary with stream order, season, degree of shading, nutrients, and water hardness (Wallace et al., 1992). Although under some circumstances, gross primary production can be high (see Hill and Webster 1982b [in Wallace et al., 1992]), typical primary production inputs appear to range from approximately 9 to 446 pounds of carbon per acre of stream per year (Keithan and Lowe 1985, Rodgers et al., 1983, Wallace et al., 1992). Primary producers in Appalachian streams include vascular plants, bryophytes and algae.

b. Allochthonous Energy Sources and Processing

Allochthonous energy sources consist primarily of leaves and woody material. However, dissolved organic carbon (DOC) from a variety of sources is an additional allochthonous energy source. Sources of DOC external to the stream include groundwater or runoff. Sources internal to the stream relate largely to leaching of organic matter from detritus or other organic matter. Fisher and Likens, in Science Applications International Corporation (1998), explain that over 90 percent of the annual energy inputs to small forested streams can be attributed to leaf detritus and dissolved organic carbon from the terrestrial environment. Webster et al. (1995) further discusses sources for organic inputs to streams.

The estimate of almost 3600 pounds of carbon per acre of stream per year developed by Bray and Gorham (1964) as a measure of leaf and wood litterfall into a stream per year, is considered to be a good estimate for input into high-gradient Appalachian streams. The mass of material input as leaf fall is generally greater than that input as woody material. However, in some circumstances the mass of input as woody material may equal that of leaf input (Webster et al., 1990).

The headwater stream (first- through third-order) is the origin for energy processing within the river ecosystem. Headwater streams in the study area are located in forested areas and are characterized by a heavy leaf canopy and low photosynthetic production. Sources of energy for headwater streams are allochthonous in origin or derived from the terrestrial environment. The vast majority of this allochthonous material arrives in the streams in the form of Coarse Particulate Organic Matter or CPOM (> 1 mm in size). Smaller amounts of other allochthonous material that is transported to the stream includes Fine Particulate Organic Matter (FPOM, 50 um – 1 um in size) and Dissolved Organic Matter (DOM) traveling from surface and groundwater flow. Microbes and specialized macroinvertebrates living in headwater streams, called shredders, feed on the DOM and CPOM, converting it into FPOM and DOM. The FPOM and DOM are carried downstream to mid-sized streams.

Because mid-sized streams (fourth- through sixth-order) are wider than headwater streams, the canopy is usually more open and more light is able to penetrate to the stream bottom. As a result, a greater abundance of algae and aquatic plants are able to grow along the stream bottom. In general, the contribution of allochthonous material derived from terrestrial vegetation in midsized streams is less than in the headwater streams. Autochthonous material, meaning material that is derived from within the stream, becomes an important component of the energy budget in midsized streams.

3. Animal Communities

a. Invertebrates

Stream order typically dictates the community structure of the resident aquatic life. Headwater streams harbor primarily benthic macroinvertebrate communities who are specialized to feed on the CPOM deposited in the system. Examples of benthic macroinvertebrates include crayfish, worms, snails and flies. The majority of benthic macroinvertebrates in headwater streams are classified as shredders and collectors, who feed on the CPOM and FPOM, and predators who feed on the other macroinvertebrates. Typical benthic macroinvertebrates found in headwater streams in the study area include insects such as mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), dragonflies and damselflies (Odonata), beetles (Coleoptera), dobsonflies and alderflies (Megaloptera), true bugs (Hemiptera), springtails (Collembola), and true flies (Diptera). Other macroinvertebrates that have been collected include crayfish (Decapoda), isopods (Isopoda), worms (Oligochaeta and Annelida) and snails (Gastropoda) (FWS, 1998; Science Applications International Corporation, 1998).

In the southern Appalachian Mountains, macroinvertebrates of several orders including Ephemeroptera, Plecopter and Trichoptera have been found to be rich in species, including many endemic species and species considered to be rare. This diversity and unique assemblage of species has been attributed to the unique geological, climatological and hydrological features of this region (Morse et al., 1993, Morse et al., 1997). Many biologists agree that the presence of a biotic community with such unique and rare populations should be considered a critical resource.

b. Vertebrates

Two groups of vertebrates, fish and salamanders are the major stream-dwelling vertebrates in the study area. Typically, salamanders occupy small, high-gradient headwater streams while fish occur farther downstream. Predation by fish is believed to restricts salamanders to the smaller streams or the banks of large streams (Wallace et al., 1992).

Fish species present in headwater streams tend to be representative of cold water species, and primarily sustained by a diet of invertebrates (Vannote et al, 1980). As found with invertebrates and amphibians, the fish assemblages of the Appalachians tend to contain a relatively large number of endemic and unique species. Some fish species collected in the pristine headwaters of West Virginia include blacknose dace (*Rhinichthys atratulus*), creek chub (*Semotilus atromaculatus*), and slimy sculpin (*Cottus cognatus*) (FWS, 1998).

Many different kinds of amphibians and reptiles live in or near streams and wetlands. Many types of amphibians in particular are unique to the Appalachian regions. The West Virginia Division of Natural Resources has published a pamphlet, "Amphibians and Reptiles of West Virginia: A Field Checklist." This list mentions 46 amphibious species and 41 reptilian species, the vast majority of which are most likely located throughout the study area within suitable habitat of Kentucky, Tennessee, and Virginia. Many of these amphibious and reptilian species may be primarily terrestrial, but live in proximity to aquatic areas such as streams and wetlands. In addition, several species strictly rely on the presence of streams or wetlands for at least part of their life cycle (Conant and Collins, 1991).

It is difficult to predict what fish species will be found in a stream with a particular stream order designation. For example, one would expect a much higher diversity of fishes in a first-order stream that empties directly into a fourth-order stream than would be found in a first-order stream that joins with another first-order stream to form a second-order stream. It would be wrong to interpret the higher diversity in the first case as being indicative of a healthier or cleaner stream. In general, fish diversity is greater in higher-order streams, but certainly so-called “big river” fishes will enter first-order streams, when these streams drain directly into higher order lotic systems (Stauffer, 2000).

4. Ecosystem Function

The value of headwater streams in the study area was the subject of a symposium held in April 1999. The proceedings of this symposium are summarized below.

Small streams play a pivotal role in lotic ecosystems. Small streams:

- Have maximum interface with the terrestrial environment with large inputs of organic matter from the surrounding landscape
- Serve as storage and retention sites for nutrients, organic matter and sediments
- Are sites for transformation of nutrients and organic matter to fine particulate and dissolved organic matter

- Are the main conduit for export of water, nutrients, and organic matter to downstream areas (Wallace in Symposium on Aquatic Ecosystem Enhancement at Mountain Top Mining Sites, January 2000)

The major functions of headwater streams can be summarized into two categories, physical and biological (Wallace in Symposium on Aquatic Ecosystem Enhancement at Mountain Top Mining Sites, January 2000):

Physical

- Headwater streams tend to moderate the hydrograph, or flow rate, downstream
- They serve as a major area of nutrient transformation and retention
- They provide a moderate thermal regime compared to downstream waters- cooler in summer and warmer in winter
- They provide for physical retention of organic material as observed by the short "spiraling length"

Biological

- Biota in headwater streams influence the storage, transportation and export of organic matter
- Biota convert organic matter to fine particulate and dissolved organic matter
- They enhance downstream transport of organic matter
- They promote less accumulation of large and woody organic matter in headwater streams
- They enhance sediment transport downstream by breaking down the leaf material
- They also enhance nutrient uptake and transformation

In summary, light and the input of allochthonous material are the two limiting factors in the contribution of energy to a river ecosystem as a whole. When an energy source is altered or removed in the upstream reaches, downstream biological communities are also affected. The value of headwater streams to the river ecosystem is emphasized by Doppelt et al. (1993): "Even where inaccessible to fish, these small streams provide high levels of water quality and quantity, sediment control, nutrients and wood debris for downstream reaches of the watershed. Intermittent and ephemeral headwater streams are, therefore, often largely responsible for maintaining the quality of downstream riverine processes and habitat for considerable distances."

C. TERRESTRIAL HABITATS

Forests dominate the terrestrial habitats of the study area. Data provided by the West Virginia Gap Program indicates that at least nine forest types are located within the WV portion of study area. Dominant among these forest types is the diverse mesophytic hardwood forest. The diverse mesophytic forest is among the most diverse forest type in the southeastern United States (Hinkle et al.,1993). Yellow poplar (*Liriodendron tulipifera*) is the predominant species in the diverse mesophytic forest type in the Central Appalachians (Hicks, 1998); however, dominance is shared by a large number of species including various oaks (*Quercus* spp.), maples (*Acer* spp.), beech (*Fagus grandifolia*), hickories (*Carya* spp.), cherry (*Prunus* spp.), and black walnut (*Juglans nigra*), to name but a few (Strausbaugh and Core, 1997). This forest type is characterized by a diverse understory of trees that never attain canopy status and wildflowers are common.

The cove hardwoods are a type of mixed mesophytic hardwood forest. They are included here because species common to the cove hardwoods are likely common to the mixed mesophytic hardwood forest type as well due to their spatial relationship. Cove hardwoods are found in ravines, coves and along north-facing slopes. Often, pure stands of yellow poplar are the hallmark of the cove hardwood forests (Hicks, 1998). Species composition can be very diverse with red oak (*Quercus rubra)*, pin cherry (*P. pennsylvanica*), black cherry (*P. serotina*), paper birch (*Betula papyrifera*), yellow birch (*B. alleghaniensis*), aspen (*Populus* spp.), sugar maple (*A. sacchaum*), red maple (*A. rubra*), and Eastern hemlock (*Tsuga canadensis*) dominating (Strausbaugh and Core, 1997). Local species dominance patterns are often small scale with significant species changes over relatively short distances.

Due to the abundance and variety of fruits, seeds, and nuts the diverse mesophytic forest type provides excellent habitat for wildlife and game species alike. Wildlife species richness of the mixed mesophytic forests of the study area are considered one of the most diverse in the United States (Hinkle et al., 1993). Factors associated with the terrestrial habitats of the study area are described in detail below.

1. Defining Factors Associated with the Terrestrial Habitat

a. Forest Fragmentation

The phrase forest fragmentation describes a formerly continuous forest that has been broken into smaller pieces. Forest fragmentation occurs when an activity removes some forest and leaves remaining stands in smaller isolated blocks. The pattern of forest loss is as important as the amount of loss. A checkerboard pattern of remaining forest represents more forest fragmentation than clumps of forest of the same total acreage.

The degree of forest connectivity can affect the sustainability of forest species within and among a landscape. However, connectivity can sometimes be misleading. For example, a series of small woodlots may be connected and creating substantial area yet they make lack the interior forest needed to support certain species. Areas with large blocks of continuous forests support a variety of interior forest species, e.g., neotropical migrants, pileated woodpecker, etc., whereas areas with small fragmented forests tend to support fewer interior forest species with more edge dwelling species.

b. Edge Habitat

Edge habitat occurs at boundaries between different types of land cover. Many wildlife species require resources in two or more vegetation types and thus require edge habitat. Some species of birds forage in grasslands and nest in forests. Nest parasitic bird species such as brown-headed cowbirds (*Molothrus ater*) have their greatest impact on other native species in areas where edge habitat is common (Robinson et al., 1995 and citations within). For instance, the brown-headed cowbird is a native species of open prairies of the American mid-west but has spread to all of eastern North American due to the conversion of forests to agricultural lands. This species is essentially absent from interior forests but common along edge habitat ecotones. As forests are fragmented and edge habitat increases, interior species such as the ovenbird, hooded warbler, and wood thrush, are subject to nest parasitism by cowbirds, and thus decreased rates of reproductive success (Buckelew and Hall 1994, Robinson et al., 1995).

The outer boundary of a forest is not a line, but rather a zone that varies in width. Meffe and Carroll (1994) report of edge zones in Wisconsin that are as small as ten meters to those in Queensland that are as great as 500 m. The breadth of edge zones may well have to do with microclimatic differences associated with the edge. Edge zones are usually drier and receive more sunlight than interior forests and thus have a different floral composition, favoring shade-intolerant species. Microclimatic edge effects such as this may have a negative effect on interior species of the patch through altering of the physical environment and competition for resources. On the other hand, due to the different microclimate associated with the edge ecotone, these habitats are often more diverse than the interior habitat.

Edge effect is usually used to describe two phenomenon associated with edge habitats. Often, the phrase edge effect is used to describe the negative influence that edges have on the interior of a habitat and on the species that use the interior habitat, like the microclimatic differences described above. Furthermore, edge effect can be used to describe the increase in species richness often observed at the ecotone of forest edges.

c. Patches

Patch size refers to the area of a particular habitat or reserve within a landscape. The basic species-area relationship (MacArthur and Wilson, 1963) implies that larger patches sustain a greater number of species of a region than do smaller patches. This is due, in part, because large patches have an increased chance for immigration. Another reason that this relationship is due to an increase in habitat heterogeneity as patch size gets larger. Larger patches are also more likely to be able to accommodate disturbances than smaller patches. As patch size decreases forest perimeter-to-volume ratios increase, thereby increasing edge effects and reducing the amount of interior habitat.

Another aspect of patch size is isolation. Small, isolated patches are more prone to species extinctions than large patches and small groups of closely spaced patches because they are less likely to be colonized (MacArthur and Wilson, 1963). Isolation leads to a loss in genetic diversity and often to an increase in deleterious gene frequencies within the isolated populations. Isolation is a major cause of vicariant speciation but at the same time it is a major cause in species extinction (Brown and Lomolino, 1998). Vicariant event speciation describes the presence of two closely related yet disjunct species that are assumed to have been created when the range of their ancestor was split.

d. Biological Integrity and Potential Ecological Condition

Biological integrity refers to the ability of an environment to support and maintain a balanced and integrated adaptive assemblage of organisms having species composition, diversity, and functional organization comparable to that of an undisturbed habitat within the same region (Karr et al., 1986). Generally, the term biological integrity is limited to use of aquatic habitats where it has received much recent attention because of the terms use in the Clean Water Act (section 101(a)). However, the principal of biological integrity applies to all ecosystems. One measure of the biological integrity of the terrestrial environment is the potential ecological condition (PEC), also known as the bird community index (O'Connell et al., 1998). PEC and how it is calculated will be discussed in detail in Chapter II. Methodology, later in this report. Bird guilds are used as models in the PEC calculation, however, the results are applicable for all taxa that depend on interior forests (O'Connell et al. 1998; O'Connell et al., 2000). PEC is an effective measure of biologic integrity in that it takes into account measures of forest cover, interior forest habitat, and human use conditions to generate a value for a location (watershed or study area) that can be compared with values modeled from other locations or under different disturbance regimes. These modeled changes in PEC are equivalent to a change in biological condition, thus the link between biological integrity and PEC.

e. Interior Forest Habitat

A variety of wildlife species require large tracts of continuous forest cover for their survival. For example, the cerulean warbler, *Dendroica cerulea*, is a common bird of mixed mesophytic and Appalachian oak forests in West Virginia. This migratory species commonly occupies the heavily leafed canopy of mature forests during summer months and is rarely seen. Studies suggest that a minimum area of 700 hectares is required for sustaining a viable population of this species (Buckelew and Hall 1994). Robbins et al. (1989a) addressed habitat area requirements for a large number of forest-dwelling birds in the central Appalachians. Of the 75 forest and forest-edge species included in the study, none was restricted to small forests and many had minimum breeding habitat requirements greater than 3,000 hectares (Robbins et al., 1989b).

There are several reasons why interior forest habitat is required for the breeding success of many forest birds. One factor is the increased diversity of microclimates within larger forest patches. A second reason is the significantly higher rates of nest predation in small forest patches (Brittingham and Temple, 1983; Small and Hunter, 1988). Finally, Robbins et al. (1989) suggests that the short breeding period associated with neotropical migrants when compared to year-round residents leads to increased susceptibility to negative environmental influences like nest predation and brood parasitism. In short, many neotropical migrant species are forced to breed in large tracts of interior forest because they only have time for one breeding event per year.

2. Relating the Terrestrial Factors to Biodiversity

The term biodiversity is used to describe the variety of living organisms and can be applied to various levels of biological organization. For example, biodiversity may be implied at the genetic, species/population, or ecosystem levels. Often, biodiversity is used to describe the variety of a higher taxonomic order, birds for instance, in a region or study area. The terrestrial factors described above all have the potential to exert a considerable affect on biodiversity at one or numerous of the levels biological organization and scale. Below is some discussion that attempts to relate the terrestrial factors discussed above with biodiversity at both the watershed (local) and study area (regional) spatial levels.

a. Forest Fragmentation

Some of the effects of habitat fragmentation occur almost immediately while others develop over decades (Meffe and Carroll, 1994). The most notable effect of fragmentation is the loss of a particular species from the fragmented landscape. Data suggests that habitat destruction is responsible for more than one-half of the species lost. Endemic species, those with a very narrow distribution range limited to a specific habitat, may exhibit immediate loss or local extinction of populations. Meanwhile, species that are not rare or endemic may be affected at a much slower rate.

Take for example the reduced nesting/reproductive success of midwestern (United States) migratory birds in response to forest fragmentation (Robinson et al., 1995). Robinson et al. (1995) suggests that forest fragmentation leads to increase nest predation and ultimately to establishment of migratory bird populations that are unable to sustain themselves without immigration from non-fragmented habitats. Populations that exist this way are referred to as “sinks” depending solely on immigration from the “source” population for survival (Pulliam, 1988). By definition, a source habitat has reproductive success greater than local mortality, whereas, a sink habitat has mortality rates higher than reproductive rates. Thus, individuals living in sink habitats are on the brink of local extinction. However, so long as the source population is unaffected and immigration routes remain open, recolonization will likely take place following local extinction.

The reason that sink populations are unable to achieve reproductive success greater than mortality is generally a condition of the local environment. This condition may be associated with isolation, introduced species, loss of critical habitat, or any of a number of possible conditions. In any case, the effect likely exhibited on the species is the loss of a genetically effective population size. Genetic diversity is a key for the long-term survival of populations. Genetic variation is important to both fitness of the individual and adaptive change. Small populations generally are less genetically diverse than large populations and this decrease in genetic diversity tends to result in a reduced evolutionary adaptive fitness (ability to change with a changing environment) and ultimately to local extinction.

Thus, we can conclude that forest fragmentation exerts its effect on biodiversity at various levels of biological organization and spatial scales. A decrease in genetic diversity may lead to local extinction of a population while the local extinctions of many populations in a region may lead to a decrease in biodiversity at a broader landscape level.

b. Edge Habitat

Ecological processes that structure biological communities may change as a result of edge effects (Meffe and Carroll, 1995). These changes may be the result of an increase in those species that are attracted to edges and the decrease in those species that have characteristics that make them unsuitable for edge habitat. For example, Klein (1989) describes the decline of beetles from edge habitat compared to interior forest because beetle larvae were desiccating in the drier soils along the edge. It is unlikely that edge habitat itself would have considerable impact on genetic biodiversity. Obviously, habitat fragmentation associated with edge habitat does have a major impact on genetic variation as described above. The affect that edge habitat has on biodiversity is likely more at the species/community and ecosystem levels. Edge habitats tend to attract certain species of animals (Gates and Gysel, 1978) and this would lead to a shift in the composition of ecological communities.

At the broader landscape level, increased edge habitat would lead to an increase in edge favoring species and a decrease in numbers of those species associated with interior forests.

c. Patches

Patches and habitat fragmentation go hand-in-hand. Therefore, the affects that fragmentation has on genetic, species/population, and ecosystem diversity described above also apply to this topic. As fragmentation increases so do the number of patches in the landscape. Furthermore, an increase in fragmentation is generally associated with a decrease in the average size of patch types. One aspect of patches is associated with rare and endemic species. Some species have life history characteristics that limit their distribution to a small, defined patch or set of patch types. Thus, loss of a critical habitat across the region may lead to the complete extirpation of a species or group of species from the landscape.

d. Biological Integrity and Potential Ecological Condition

The measure of PEC is basically a measure of the biological condition of the terrestrial habitat. It is a tool that assigns a value to an area that can be interpreted as a measure of biodiversity. Since PEC takes into account ecosystems, not individuals, it is a tool that approximates the ecosystem biodiversity. Quite simply, PEC is a measure of the terrestrial ecosystem biodiversity at either the local (watershed) or regional (study area) level.

e. Interior Forest Habitat

Interior forest habitat is important to many species, in particular birds. Birds exhibit many traits that make them excellent indicators of ecological conditions at both a local and regional level (USEPA 2000). Ecological indicators describe the condition of an ecosystem or one of its critical components. Different bird species require different habitats for foraging, shelter, and breeding. Thus, bird populations are linked to an ecological condition and both are linked to a habitat or land cover type.

Many of the birds of the study area have minimum forest area requirements. These birds are considered forest interior species and their presence in the landscape is a good indication that excellent ecological conditions exist. Robbins et al. (1989) defined habitat area requirements for 75 species of birds in the Middle Atlantic States. Among the 75 birds included in the study, 19 were neotropical migrants. Declines in populations of neotropical migrants from eastern states have been well documented (Hutto, 1988; Robbins et at., 1989b; Penhollow and Stauffer, 2000). Causes for neotropical migrant population declines have been attributed to agriculture, urban and suburban sprawl, and deforestation (Askins et al., 1990). These declines are likely due to factors associated with forest fragmentation, as described above. Once habitats of contiguous interior forest become fragmented the factors described above (see Forest Fragmentation discussion) that effect biodiversity come into play.

D. RIPARIAN AND WETLAND HABITAT

Wetlands and riparian zones may occur along streams. Wetlands and riparian zones may influence the physical characteristics of streams, thereby affecting stream habitats. In addition, wetlands and riparian zones may be used by stream biota directly during periods of elevated flow. Wetlands are crucial transition zones between terrestrial and aquatic habitats. They are defined as areas "that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (COE, 1987). Wetlands can be found on floodplains along rivers and streams (riparian wetlands). Typical steep geomorphology of headwater streams usually prohibits the formation of a floodplain, so wetlands are usually restricted to small depressional areas. As the gradient of the land becomes more gradual, more wetlands are found on the floodplain of the stream. Wetlands associated with rivers can take the form of forested wetlands, emergent marshes, wet meadows or small ponds. The unique characteristics and vegetative composition of wetlands provide important habitat for many species of aquatic macroinvertebrates, amphibians, and reptiles.

II. METHODOLOGY

A. LANDSCAPE ECOLOGY

Landscapes are comprised of aggregations of various vegetation or land cover types (referred to as patches) that combine to create patterns or mosaics on the earth's surface. Such patterns have developed as the result of climatic influences, site quality, natural disturbances, plant succession, and human activity. Landscape ecology is a discipline that focuses on understanding the causes and consequences of changes in landscape patterns. A fundamental tenet of landscape ecology is that humans and their activities are recognized as an integral part of the environment (USEPA, 1997). Numerous metrics have been developed to quantify changes in landscape patterns over time and space. Changes in patch diversity, size, proximity, edge, contagion, and connectivity have implications to floral and faunal communities as well as other natural features such as water ways.

Mountaintop mining and valley fill activities significantly affect the landscape mosaic. Landcover changes occur as forests are removed, the topography and hydrology is altered, and vegetation is eventually re-established. The result is an area drastically different from its pre-mining condition. Soil qualities are different, the vegetative community has a different structure and composition, and habitats are altered. Over time, if left unmanaged, forest succession will transform vegetative communities but the rate of this change is heavily dependent on the reclamation intent (i.e. post mining land use) and practice.

Scale plays an important role in landscape ecology. With changes in scale different patterns emerge or recede. The scale of analysis should be appropriate to the phenomenon under study. Furthermore, organisms perceive scale differently. The range of a salamander may be a single acre or less while a black bear may range over many square miles therefore they will be affected differently by the same landscape modification event. One species' entire range may be eliminated whereas another can shift its activities to another location. The study discussed here summarizes data on a watershed scale and is not intended to assess conditions for areas less than 5,000 to 10,000 acres in extent. Because of the limitations inherent to the input data, it is not appropriate to assess impacts at a finer scale. Indeed, any attempt to make a site specific evaluation would be a misuse of the data and any conclusions from such an evaluation would be highly suspect.

Landscape indicators are direct or indirect measures of environmental parameters or combinations of parameters. They have been likened to economic indicators such as housing starts, factory orders, and unemployment percentages. These indicators are used by economists to gauge national economic condition. No single indicator tells the entire story but by evaluating several one may perceive trends and make predictions. Likewise, by evaluating several indicators for a specific watershed or group of watersheds it is possible to assess a level of ecological integrity or vulnerability to degradation relative to other watersheds. Indicators also serve as monitoring tools to assess ecosystem condition as landcover modifications occur. To assess cumulative impact it is necessary to look a variety of indicators and make comprehensive analyses on the collective. It is also important to realize that some indicators are strongly correlated with one another.

B. DESCRIPTION OF GEOGRAPHIC DATA

1. Stream Network

The GIS stream network was generated from DEM data using standard ARC Info commands. The streams are "synthetic" in that they were not generated by conversion of existing maps, such as orthophotographs or USGS 7.5' quad sheets, into digital format. Rather, they were generated using a digital elevation model (DEM). A DEM is a digital representation of the earth's surface based on a regular series of sample elevation points organized in a 30x30 meter grid. DEM's can be used to model the direction of water flow and accumulation of flow.

For the data used in the cumulative impact study a contributing area of 30 acres was selected to generate a stream. There is some uncertainty is this selection given that permits in Kentucky have indicated perennial streams in watersheds smaller than 10 acres. Therefore; the synthetic stream network may underestimate stream length. This 30 acre threshold is supported by studies by the United States Geological Survey (USGS), West Virginia Water Resources Division District Office to field determine the ephemeral-intermittent and intermittent-perennial stream boundaries. The mean drainage area for 33 sampled ephemeral reaches in the West Virginia coal region was 30 acres (USGS unpublished data 2000); therefore, the synthetic streams are considered to represent ephermeral, intermittent, and perennial streams. The detail of these data exceeds that of USGS 1:24,000 scale stream networks (Figure II.C-1) which generally capture perennial and inconsistently ephemeral streams. The synthetic stream network was not ground truthed.

2. Land Cover Data

The forest loss was calculated using the National Land Cover Dataset (NLCD). The NLCD was produced as a cooperative effort among six programs within four U.S. Government agencies: the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP); the U.S. Geological Survey's (USGS) National Water Quality Assessment Program (NAWQA); the Department of Interior National Biological Service's (NBS) Gap Analysis Program (GAP); the USGS's Earth Resources Observation Systems (EROS) Data Center; the National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program (C-CAP); and the EPA's North American Landscape Characterization (NALC) project. It provides a consistent, land cover data layer for the conterminous U.S. using early 1990s Landsat 5 thematic mapper (TM) data. The goal was to select TM scenes acquired in 1992, plus or minus one year, to allow for basic temporal consistency across the United States. Scenes were constrained to have a cloud coverage of no greater than 10 percent and to be of high digital quality.

These data can be used for landscape scale analysis in various disciplines such as wildlife ecology, forestry, or land use planning. The data scale is 1:50,000. The NLCD classification contains 21 different land cover categories. The National Land Cover Dataset has a spatial resolution of 30 meters and supplemented by various ancillary data. Map projection of original NLCD data set converted from Albers Conical Equal Area to the Universal Transverse Mercator, Zone 17 coordinate system.

The additional forest metrics that were calculated only for the West Virginia portion of the study area (ie. PEC, forest fragmentation and forest edge) were calculated using WV GAP Land Cover. This land Cover data set is a raster representation of vegetation/land cover for the state of West Virginia. This data can be used for landscape scale analysis in various disciplines such as wildlife ecology, forestry, or land use planning. The data have been developed for inclusion in the Gap Analysis Program. Data scale is 1:50,000. There are 26 land cover codes. Land cover data were collected as part of the West Virginia Gap Analysis Project, a collaborative effort between West Virginia University's Natural Resource Analysis Center, the West Virginia Cooperative Fish and Wildlife Research Unit, the West Virginia Division of Natural Resources, and the Biological Resources Division of the US Geological Survey. The source data were acquired from multiple 30-meter Landsat imagery obtained between 1992-1994 and field checked with videography. Preliminary results published 2000.

3. Riparian Habitat

While most habitats are mapped using land cover obtained from remotely sensed imagery, certain reptiles and amphibians rely on wetland or riparian habitat features that cannot be readily mapped from imagery therefore a separate model of riparian habitats is necessary to assess the relative sustain ability of these species within each future mountaintop mining scenario. The West Virginia Gap Analysis project (www.nrac.wvu.edu/gap/) created a model of these habitats using raster modeling techniques (with the aide of Geographic Information Systems) based on stream hydrology, elevation, slope and ancillary data including the USFWS National Wetlands Inventory (Strager et al., 2000.) This modeled habitat shows mapped stream, wetland, open water, and riparian habitats throughout the state at a much more detailed level than the WV-GAP land cover and allows for prediction of amphibian and reptile distribution. These data are used to estimate loss of these habitats. These data are intended to be used at a scale of 1:100,000 or smaller for the purpose of assessing the conservation status of vertebrate species and vegetation types over large geographic regions.

The model of potential wetland and riparian habitats is created from the combination of the riparian areas surrounding streams, existing wetlands data, and forested land cover data. This model is used as an input for species distribution modeling. Stream hydrology, percent slope, and digital elevation data were combined to produce relative cost path distance grids for headwater, small, and large streams. Path distance grids were derived from the “cost” incurred by movement from source cells (streams) to non-source cells. The cost of movement between cells is weighted by an impendent factor (slope) applied over surface distances (derived from digital elevation data). The resulting grids can be used to approximate riparian areas surrounding streams. Forested land cover and existing wetlands data were also input to the model of potential wetland and riparian habitats.

4. Mine Data

Mine permit GIS layers were obtained from the United States Office of Surface Mining (OSM). The goal was to compile GIS layers representing approved surface mining permits from the ten year time period of 1992-2002 within the four state EIS study area. Mine permit polygons are based on maps submitted to the SMCRA authority by mine operators seeking to obtain a permit. The mine data set was compiled in such a fashion as to be as consistent as practicable among the states in the study area; however, there were differences in the available digital data sets. Data for the prior ten years were available for Virginia, West Virginia, and Tennessee. Only four years of permit data were available for Kentucky.

OSM filtered the GIS data to exclude operations permitted prior to 1992, as well as permits which represent underground mining, preparation facilities, coal waste disposal areas, etc. The data were filtered so that only surface mining permits are included. The permit coverage was "clipped" to include permits located only within the EIS study area. The following are detailed descriptions of the mine data specific to each state within the study area. The list of permits included in the permit data set are presented in Appendix B.

Kentucky

<u>Original Source Description</u>

The Department for Surface Mining Reclamation and Enforcement (DSMRE) currently makes available scanned and georeferenced mining and reclamation plan maps and annual underground maps for permits issued by the Department. Mining and reclamation plan (MRP) maps are required to be submitted with an application for a permit to conduct surface coal mining and reclamation operations in the Commonwealth of Kentucky. MRP maps are generally drawn on an enlarged USGS seven and one-half (7 1/2) minute topographic map at a scale of between 400 and 600 feet to the inch. Permitted surface and underground mine boundaries and facilities associated with coal mining operations are shown along with names and locations of streams and other bodies of water, roads, buildings, cemeteries, oil and gas wells, public parks, public property, and utility lines.

The source of the GIS mine polygons for Kentucky used in this cumulative impact study are the surface mining overlay maps maintained by the Kentucky Department of Surface Mining Reclamation and Enforcement (DSMRE). These maps consist of frosted mylar sheets that overlay 7 ½ minute USGS topographic maps. DSMRE staff draw permitted surface and underground mine boundaries and selected other features in ink onto the mylar. DSMRE GIS specialist scanned and georeferenced these mylar overlays, which are now available to the pubic for downloading. Here is the site link where the scanned may be downloaded: http://kydsmre.nr.state.ky.us/gis/data.htm. MRP maps georeferenced beginning in July 2002, and all georeferenced underground maps are projected in the NAD83 Kentucky Single Zone Coordinate System. MRP maps processed prior to July 2002 were georeferenced in NAD83 Kentucky State Plane North or South zone coordinates.

Currently six series of overlays are available both in hardcopy and digitally. Each series represents a time period in the permitting of surface coal mining in Kentucky.

Series I: Areas permitted from 1977 to March 1, 1981, and which were active as of January 1, 1981.

Series II: Areas permitted from 1961 to 1977, and which were inactive as of January 1, 1981.

Series III: Areas permitted from March 1, 1981 through January 18, 1983.

Series IV: Areas permitted under the permanent program after January 18, 1983 and through April 1, 1986.

Series V: Areas permitted under the new permanent program after April 1, 1986 and through August 1, 1995.

Series VI: Areas permitted after August 1, 1995 and through August 31, 1999.

Series VII Areas permitted after September 1, 1999 and through April 30, 2000. (Series VII has been converted to GIS polygons by DSMRE.)

For the purposes of the cumulative impact analysis only the information from Series VI and VII were used. Series VI consists of three primary overlay sheets: (1) Polygon Layer - closed polygons - permit boundaries, etc… (2) Line Data Layer - lineal lines - roads, conveyors, utilities, etc… and (3) Point Data Layer - small ponds, sampling sites, mine adits, etc. Overlaying permits will be drawn on separate sheets of Mylar, thus there may be more than one polygon layer sheet (Sheet 1, Sheet 2, etc…). Hatched lines denote underground shadow areas. Areas of less than full recovery have a greater opening between hatch marks and recovery percentage is indicated.

Description of Map Symbols and Codes for KY data

The mining overlay maps are identified by the 7 ½ minute quadrangle name. Alpha characters are assigned to each permit number and appear as the first portion of the attribute code assigned to each map feature. The alpha codes are generally listed in alphabetic order and expand to multi-lettered codes (AA, BB etc.) to include all permits pertaining to a given quadrangle. Alpha codes and the specific permit number to which they correspond are listed at the bottom of the overlay. Adjacent maps that share the same permit boundary have, in most cases, the same alpha code on both maps. The number which follows the alpha code is a one-, two- or three-digit number defining the major category in which a mining feature falls (i.e. mining, fill areas, haul roads, etc.). Often a sub-category is used to describe a mining feature in greater detail. An example of a feature attribute code is 'A-610'. The code refers to a sediment structure (6), embankment type (10), within the permit number assigned 'A'. Areas common to more than one permit number are labeled with the alpha character and feature attribute codes of both permit numbers with a comma placed between them.

The permit features are drawn as dashed lines, solid lines, dash-dot-dot lines, or single dots. Haul roads and railroads are drawn as dashed lines unless they correspond to the permit boundary, in which case the permit boundary takes precedence. Features that appear as solid lines or polygons include mining areas, fill/storage areas, permit boundary areas, face-ups, and reference areas. Points are used to represent features of small acreage such as sediment structures, monitoring points and underground mine openings. Hatched lines indicate underground areas.

Due to the influx of new mining permits and the absence of some permits at the time of drafting, these overlays are not 100% comprehensive. The updating procedure (acreage additions and deletions) was initialized to keep the mining operations overlays as up-to-date as possible.

Description of Digital Data Base Queried for the Cumulative Impact Study for KY data

Staff from OSM's Pittsburgh Office downloaded the Series VII and VI digital information from KY DSMRE FTP server on October 7, 2002, and October XXX, respectively.

The Series VII GIS data was filtered to retain only those mining disturbances associated with surface mining activities. All polygons associated with the activities coded as "face up", "load out", "prep plant", "surface auger", "slide", "stockpile", or "underground" were deleted from consideration for the purpose of the cumulative impact analysis. Further, using the boundaries of the EIS study area in Kentucky, a GIS specialist at OSM Pittsburgh Office used readily available querying tools in ESRI ARCVIEW software to select only those surface mining permits that were located wholly or partly within the EIS study area. This filtered digital data for Series VII, which consisted of multiple polygons for surface mines, were forwarded to EPA's Wheeling Office.

The Series VI scanned and georeferenced mylars posed a more challenging task. Staff from OSM Pittsburgh Office used specialized software (Able Software R2V for Windows) to convert the digital picture images (rasters) to vectorized features (polygons, lines, and points). Once converted to GIS polygons, features representing surface mining disturbances were retained and other disturbances (such as underground mining, preparation plants, augering areas, face-up areas, stockpiles, ect) were eliminated. Further, using the boundaries of the EIS study area in Kentucky, a GIS specialist at OSM Pittsburgh Office used readily available querying tools in ESRI ARCVIEW software to select only those surface mining permits that were located wholly or partly within the EIS study area. This filtered digital data for Series VII, which consisted of multiple polygons for surface mines, were forwarded to EPA's Wheeling Office. Appendix B contains a list of digital mining polygons from Kentucky forwarded for inclusion in the cumulative impact study.

Tennessee

Original Source Description

The source of the GIS mine polygons for Tennessee used in this cumulative impact study is the a digital geographic database of coal mining permit boundaries in Tennessee produced by the U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement (OSM) in Knoxville, Tennessee. It consists of georeferenced digital map data and descriptive attribute data. OSM Knoxville Field Office Geographic Information System (KFO GIS) Team developed this information from public records. The source for most of these records is the permit application submitted by coal mining operators for review and approval by OSM to conduct surface coal mining operations at specific locations in the State of Tennessee. These materials are a working resource of OSM and are contained in its file rooms and archives in paper format. Data contained in these materials were converted to digital format generally through digitizing paper maps onto a planimetrically correct base.

Selected features from the last approved Mining Operation Plan maps and Environmental Resources maps contained within a permit application submitted by a coal mining operator to the Office of Surface Mining (OSM) were manually digitized into an individual coverage using the ArcEdit subsystem of ArcInfo Workstation. Each map was georeferenced using geographic features found in common on both the paper manuscript (map) and on Digital Raster Graphic (DRG) images of standard 7.5-minute series USGS topographic quadrangle maps as displayed on a computer monitor. These DRG's were acquired from the U.S. Tennessee Valley Authority and were transformed to Tennessee State Plane, NAD 27 coordinate system by OSM. After initial digitizing on a standard digitizing table, the digital data set was inspected on a computer monitor and visually compared against the paper manuscript. Coverage feature classes were edited to correct digitizing errors. Attribute data was added to describe features contained in the coverage. Individual coverages were then posted to the Knoxville Field Office Geographic Information System (KFO GIS). Each individual coverage was then incorporated into a master coverage of similar features. All compilation, digitizing, and quality control were performed by GIS specialists at the OSM in Knoxville, TN.

The accuracy of these digital data is based on features represented on source maps supplied by various coal mining operators. In general, these features were drawn by hand on paper reproductions of standard 7.5-minute series USGS topographic quadrangle maps enlarged to a scale of 1"=400' and were submitted as Mining Operation Plan maps or Environmental Resource maps in a permit application for approval by OSM to conduct surface coal mining operations at a specific location. It is not known whether these paper reproductions of the standard USGS topographic maps meet National Map Accuracy Standards. OSM digitized selected features from each paper source map using a minimum of four georeferenced control point locations (tics). Approximately 95 percent of the maps resulted in a Root Mean Square (RMS) error of less than 10 feet as reported by the software during calibration. None exceeded 25 feet. The difference in positional accuracy between the actual feature location on the ground and their digitized coordinates as shown in this data set are unknown

This data set is a work-in-progress and represents the current amount of digital data available for this theme at the time of its production. During production, selected paper maps from individual permit applications are digitized in reverse chronological order based on the permit and/or revision approval date. This method is used to ensure that data resulting from the most recently approved permitting action for any given mining operation is always available to KFO GIS users. As the general digitizing effort continues, maps are retrieved from successively older permit applications for digitizing and data entry. Current estimates of temporal coverage for this theme extend back to approximately 1984. As new information is made available to OSM, and as resources are available to capture this information into a digital format, this data set will be amended with updated features from newly approved mining operations and also be revised to include features from older mining operations.

Although these data have been processed successfully on a computer system at OSM, no warranty expressed or implied is made by OSM regarding the utility of the data on any other system, nor shall the act of distribution constitute any such warranty. For further information about the coal mining data sets held by OSM, contact Bill Card, Geographer, Office of Surface Mining, Knoxville Field Office, 530 Gay Street SW, Suite 500, Knoxville, TN 37902, telephone 865.545.4103, x. 134, fax 865.545.4111, e-mail bcard@osmre.gov.

Description of Digital Data Base Queried for the Cumulative Impact Study for TN data

Staff from OSM's Pittsburgh Office downloaded the most current digital database from Tennessee mining permits from OSM Knoxville Field Office FTP server on September 23, 2002. This database consisted of 816 mining polygons. Staff from the Knoxville Field Office telefaxed a list of new mining permits issued by OSM from January 1992 to date that were approved to use surface mining methods or a combination of surface and underground methods to extract coal. The permits on this list met the criteria established by the EIS Steering Committee for the cumulative impact study and was used to select a subset of mine permit digital data polygons from the source database. Further, using the boundaries of the EIS study area in Tennessee, a GIS specialist at OSM Pittsburgh Office used readily available querying tools in ESRI ARCVIEW software to select only those surface mining permits that were located wholly or partly within the EIS study area. This filtered digital data, which consisted of 39 new surface mines, were forwarded to EPA's Wheeling Office. Appendix B contains a list of digital mining polygons forwarded for inclusion in the cumulative impact study.

Virginia

Original Source Description

The source of the GIS mine polygons for Virginia used in this cumulative impact study is the a digital geographic database of coal mining permit boundaries in Virginia produced by the Virginia Department of Mines, Lands, and Minerals - Division of Mined Land Reclamation (DMLR) in Big Stone Gap, Virginia.

It consists of geo-referenced digital map data and descriptive attribute data. This data set is a work-in-progress and represents the current amount of digital data available for this theme at the time of its production.

Description of Digital Data Base Queried for the Cumulative Impact Study for VA data

Staff from OSM's Pittsburgh Office downloaded the most current digital database from Virginia DMLR FTP server on September 16, 2002. This database consisted of 2358 mining polygons. Staff from OSM Big Stone Gap Field Office identified the prefix in the permit identification number (GIS Data Field "PERMIT") representing mines approved to use surface mining methods or a combination of surface and underground methods to extract coal: "11", "15", "16", and "17".

Mining permits approved by Virginia DMLR beginning from January 1992 to the most current date were selected using information provided in the GIS database (GIS Data Field "PEISSUEDT"). The permits on this list met the criteria established by the EIS Steering Committee for the cumulative impact study and was used to select a subset of mine permit digital data polygons from the source database. Further, using the boundaries of the EIS study area in Virginia, a GIS specialist at OSM Pittsburgh Office used readily available querying tools in ESRI ARCVIEW software to select only those surface mining permits that were located wholly or partly within the EIS study area. This filtered digital data, which consisted of multiple polygons for 98 surface mines, were forwarded to EPA's Wheeling Office. Appendix B contains a list of digital mining polygons forwarded for inclusion in the cumulative impact study.

West Virginia

Original Source Description

The source of the GIS mine polygons for West Virginia used in this cumulative impact study is the a digital geographic database of coal mining permit boundaries, coal extraction polygons, and fill polygons produced by the West Virginia Division of Mining and Reclamation - Information Technology Office. These datasets are derived from hardcopy permit maps submitted to DMR. Hardcopy maps were scanned and georeferenced prior to extraction of features via on-screen digitizing by West Virginia University - Natural Resource Analysis Center. All datasets have been projected to UTM zone 17, NAD27.

Description of Digital Data Base Queried for the Cumulative Impact Study for WV data

Staff from OSM's Pittsburgh Office downloaded the most current digital database from West Virginia mining permits from West Virginia Department of Environmental Protection website: http://129.71.240.42/data/omr.html. Three GIS data layers -- permit boundaries, surface mine extraction areas, and valley fill areas - met the criteria established by the EIS Steering Committee for the cumulative impact study. This data set was filtered by using the last two digits of the permit identification number (the year the permit identification number was assigned) to include only those activities associated with new surface mining permitted after January 1, 1992. Further, using the boundaries of the EIS study area in West Virginia, a GIS specialist at OSM Pittsburgh Office used readily available querying tools in ESRI ARCVIEW software to select only those surface mining permits that were located wholly or partly within the EIS study area. Appendix B includes a list of 142 West Virginia mining permits forwarded for inclusion in the cumulative impact study.

<u>60% complete WV mine data set</u>

Due to project schedules the terrestrial forest metrics, except forest loss and percent forest, were calculated using a mine permit data set for WV that was only 60% complete at the time. The mine data set was provided by WVDEP. Mine permit polygons are based on maps submitted to the WVDEP by mine operators seeking to obtain a permit. The maps were digitized by WVU Natural Resource Analysis Center (NRAC.). These WV permit maps were queried by WVDEP to extract active and pending surface mines. Specifically, surface mine permits with an inspection status of: A1 (possibly moving coal), A4 (active but no coal removed), AM (active, moving coal), IA (approved inactive), and NS (not started) were used to approximate the present and near future active surface mining regions. These selections were made under the direction of the WVDEP. The scale of the mine permit data is reported as 1:24000 by the West Virginia GIS Technical Center. The mine permit data however was incomplete because it was still in the process of conversion from hard copy to digital format at the time of this investigation (60% complete as of August 2001). To further supplement identification of present/near future mountaintop mining “foot prints”, a third source of geographically referenced surface mining data was obtained from the Tennessee Valley Authority (TVA.) TVA compared satellite imagery obtained from the early 1990’s to imagery collected in 1999 from Landsat 7. Using a technique called Normalized Difference Vegetation Index (NDVI) they identified areas that experienced a dramatic drop in vegetative cover and compared these areas to the

WV DEP permit data and aerial photographs to derive and updated spatial dataset of mining regions in the Appalachian coal region. This effort was incomplete at the time of this study. These three sources were combined in a GIS and used as an approximation of present and near future mine disturbance area. These data are suitable for use at the HUC 11 watershed scale however it is not intended for localized studies (generally below 1:100,000.)

C. METRIC CALCULATION

1. Metric List

Landscape indicators are specific metrics. The word “metric” refers to a particular GIS calculation. Metrics calculated in this study are presented in Table II.C-1.

Table II.C-1
Metric List

Habitat Evaluated	Metric (unit)
Mine	Permit area per state and for entire study area (ac)
	Mine data ratios for West Virginia (ac) - Valley fill area to mineral extraction area, Valley fill area to permit area, Mineral extraction area to permit area
Aquatic	Direct impact to streams per state and for entire study area (mi and %)
	Direct impact to streams from valley fill area in West Virginia (mi and %)
	Direct impact to streams from mineral extraction area in West Virginia (mi and %)
	Direct impact to streams from permit area in West Virginia (mi and %)
Terrestrial	Direct impact to forests per state and for entire study area (ac and %)
	Forest loss from permit area in West Virginia (ac and %)
	Forest loss from valley fill area in West Virginia (ac and %)
	Forest loss from mineral extraction area in West Virginia (ac and %)
	Forest loss from auxiliary areas in West Virginia (ac and %)
	Grassland as indicator of past mining impact per state for entire study area (ac and %)
	Non-forest land cover class area change per state for entire study area (ac and %)
	*Impacts to riparian habitats in West Virginia (ac)
	*Potential Ecological Condition in West Virginia (unit)
	*Forest edge in West Virginia (%)
	*Number of land cover patches in West Virginia (count)
	*Percent landscape of patch type in West Virginia (%)
	*Mean patch size in West Virginia (ac)

* denotes results generated previously from 60% complete permit data.
ac = acres

2. Mine and Valley Fill Area

Mine areas were calculated based on permit boundaries obtained for each state. For West Virginia identification of valley fills and mineral extraction areas within the permit boundaries was possible however this was not the case for the other states where only permit boundaries were delineated. The permit boundaries represented the mine "footprint" that was used to determine areas of impact. The mine areas were represented digitally as a series of polygons. These were converted to raster (i.e. grid cells) format with a cell resolution of 30x30 meters to facilitate merging with the landcover data. The mine permit areas were "burned" into the landcover data to generate a post-impact scenario that could be compared to the original landcover data (i.e. pre-impact) for quantification of landcover changes.

This procedure involved reclassifying any area on the original landcover grid that intersected the permit boundaries to the Surface Mine category. Calculation of mine areas was done by totaling the number of pixels of each mine class (i.e. permit area, valley fills, and mineral extraction areas) and multiplying by the pixel area (900 square meters). The result was then divided by 4047 to convert to acres.

3. Mine Data Ratios

For West Virginia, three ratios were calculated: Valley Fill : Mineral Extraction Area, Valley Fill : Permit Area, and Mineral Extraction Area : Permit Area. This was done by dividing areas which were computed as described above.

4. Direct Impact to Streams

Direct impact of mine/fill areas to streams was calculated by converting all mine regions to polygons and overlaying them with the stream line data in a GIS. This operation essentially “clips out” the portion of the stream coverage that falls within the mine/fill polygons. Length of impacted streams was calculated and percent of streams directly impacted was determined by dividing the impacted length by the total length of streams. Total stream impact was calculated by using the permit area as the disturbance area. Impact from mineral extraction area and impact from valley fill were calculated for West Virginia permits.

5. Direct Impact to Forests

Forest loss was calculated by first converting both the pre- and post-impact landcover grid to a simple forest/non-forest layer. Grid cells with the following classification were lumped into the forest class:

- ❑ Deciduous Forest
- ❑ Evergreen Forest
- ❑ Mixed Forest
- ❑ Woody Wetlands

All other categories were non-forest. Next, forested pixels were totaled and divided by the total number of pixels in the study area to determine percent forest cover. This procedure was also done for each watershed in the study area. To determine forest area, the forested pixels were totaled and multiplied by 900 square meters. The result in square meters was then converted to acres by dividing by 4047. Changes in forest cover due to mining activity was determined by comparing the results of this procedure for the pre- and post-impact landcover scenarios.

6. Percent Forest Cover

Using the forest/non-forest layer described in the previous metric the percent forest cover with each study watershed was calculated by dividing the number of forested pixels by the total number of pixels in the watershed. Possible values range from 0 to 1, with 1 indicating 100% forest cover.

7. Grassland as Indicator of Past Mining Impact

Grassland as Indicator of Past Mining Impact was calculated by summing the transitional and pasture/hay land cover class acreage. This metric was developed in an attempt to quantify terrestrial impacts from mining before 1992. Because grasslands are not common natural habitats in the West Virginia portion of the study area (Straughsbaugh and Core, 1997), it can be assumed that natural grasslands are uncommon habitat throughout the four-state study area. Therefore, the transitional and pasture/hay land cover classes can generally be attributed to reclaimed mine areas. This metric gives a general indication of past mining terrestrial impact.

8. Non-forest Land Cover Class Area Change & Percent Change

Losses to non-forest landcover classes were computed by taking the difference in the number of pixels of each landcover category between the pre- and post-impact landcover grids. This difference was then divided by the original number of pixels of each landcover type to obtain percent change. Computation of areas was done by simply multiplying the pixel totals for a category by the pixel area (900 square meters) and converting to acres. Differences in landcover arose solely from the reclassification of the original (circa 1992 NLCD) landcover to surface mines (surface mining/quarries/gravel pits) in areas that intersected mine permit boundaries as described above.

9. Impacts to Riparian Habitat

This metric calculated using prior permit data set. Having obtained the wetland/riparian habitat (described above), determining the amount of loss due to mine/fill areas was accomplished through an overlay operation. Much like the method used in the Streams Through Mines metric a clipping operation was performed to identify and quantify wetland/riparian habitats that were spatially coincident with mine/fill polygons. Once these impacted regions were identified the area of each habitat type was totaled for each watershed.

10. Potential Ecological Condition

Potential Ecological Condition (PEC) is an index intended to assess the ecological integrity of each watershed based primarily on the extent of large scale human disturbance and "local" tabulations of forest cover. This is a raster based metric. Calculation of the PEC is a multi-step process.

First, the land use/cover map for each scenario is reclassified to produce a forest/non-forest map and a human use map. The human use map is simply all the land use area associated with human activity including shrubland (which captures transitional areas such as recent clearcuts and mine sites in early reclamation stages), major highways, powerlines, populated areas, agricultural landcover, and mine/fill regions. The human use map was queried to identify areas of human use that were greater than or equal to five (5) acres in extent. These areas were then buffered by three (3) pixels (each pixel is 30x30 meters) to approximate an "edge effect." Human use areas smaller than five (5) acres did not receive a buffer and were assumed to not affect the integrity of the surrounding forest.

The next step was to calculate a local forest cover percentage for every pixel in the watershed. This is termed a "floating window" procedure and involves centering a 200 acre circle on every pixel in the watershed and determining the percent forest cover within the circle. 200 acres was determined by O'Connell et al. (1998) to be the landscape unit size within which bird communities respond to alterations in land-cover and was part of a more detailed index of biotic integrity developed for the Mid-Atlantic Highlands.

The local forest cover map was then combined with the buffered human disturbance map to arrive at a PEC value for each pixel. The possible PEC values were zero, one, and two, with zero representing the lowest ecological condition and 2 the highest. Table II.D-2 shows how the final PEC number for a pixel was determined. As shown, the highest PEC rating could be attained only when the pixel in question had a local forest cover greater than or equal to 87% and it was forested and not within the buffer around a large human use area. Furthermore, a pixel received the lowest PEC rating when it was either classified as a human use or was less than 28% forested within the 200 acre local evaluation window. Interpretations of this data should not be made for areas less than 5000 acres (CVI unpublished.)

The PEC metric is modeled on the Bird Community Index (BCI) through collaboration between the Canaan Valley Institute and developers of the BCI (O'Connell et al. 1998.) The BCI is a type of IBI

(Index of Biotic Integrity) developed to assess ecological condition on a landscape scale. The index, developed by Penn State University researchers, is based on data for breeding songbird communities under the premise that songbird community composition reflects ecosystem properties of concern such as structural complexity, interspecific dynamics, and landscape configuration (O'Connell et al. 1998.) The BCI was tested on 126 sites in the Mid-Atlantic Highlands, an area which extends in a northeast to southwest direction through Pennsylvania, southeastern Ohio, West Virginia, Maryland, and Virginia. This is a mountainous area comprising the Blue Ridge, Ridge and Valley, Allegheny Plateau, and Ohio Hills physiographic provinces (O'Connell et al. 1998). Study sites were selected to represent the entire region. BCI was found to be highly correlated with a human disturbance gradient used to rank sites and defined thresholds of land-cover change where significant shifts in BCI categories were observed. The BCI may serve as a substitute for more numerous and intensive measurements of condition and disturbance (O'Connell et al., 1998).

The PEC metric is a simplified version of the BCI based primarily on factors such as forest cover with a 200 acre vicinity of a location and a buffer around large areas of human disturbance.

Locations with high PEC values are considered to have high ecological integrity. Such areas closely resemble native conditions, largely unmodified by recent human activity. They have extensive, unfragmented forests with mature vegetation, and a closed canopy. Although most of the forests in this region have been cutover, enough time has passed to allow re-establishment of mature forests on previously logged areas or abandoned agricultural land. Mid-range PEC values represent medium integrity sites. Attributes of these sites include higher landscape diversity (i.e. a greater variety of cover types), greater contagion (i.e. interspersion of different cover types), more edge, more agricultural and mine land, less forest cover, and lower canopy height and closure when compared to high integrity areas

Low-range PEC values indicate a landscape dominated by mountaintop mining, agricultural or other human related activities. Forest cover is less than 28% at the 200 acre scale and trees are generally smaller with a more open canopy and interior conditions are non-existent.

11. Forest Edge

The forest edge metric was calculated for each scenario using the forest/non-forest map. Every forested pixel in a watershed was evaluated in the four cardinal directions to determine the presence of an adjacent non-forest pixel. If a non-forest pixel was found bordering a forested pixel that pixel was considered to be a forest edge. The number of forest edge pixels were totaled for each watershed and divided by the total number of forested pixels to obtain the forest edge metric. Values fall within the zero to one range where zero represents no forest edge and one represents the maximum possible if every forest cell were adjacent to a non-forest cell.

The significance of this metric is as follows. Fragmented forests have more edge habitat (areas along the boundaries between different types of land cover) than non-fragmented forests. Irregularly shaped forest patches have more edge habitat than simple shaped forest patches due to the amount of perimeter per unit area. Small amounts of forest edge positioned naturally within the landscape can be beneficial to both the forest itself and some wildlife. The edges provide ecotones where food sources, habitat, and energy sources are enhanced. The creation of more forest edge habitat often corresponds to an increase in local species diversity as "edge" species are attracted to the region. However, the creation of edge habitat can also lead to the elimination of forest interior species and the encroachment of diseases and invasive exotic species (Jones, 1997). In addition, trees along the forest edge are subjected to greater variations in microclimate and greater storm damages. What determines "too much" edge cannot be answered without ascertaining impact on a particular species since species differ in their edge requirements and/or tolerance.

12. FRAGSTATS Metrics

Three metrics were calculated using FRAGSTATS, a program developed to quantify landscape pattern based on land cover data where regions of the same cover type are considered patches and groups of patches of a land cover type comprise classes.

The Number of Landcover Patches is the number of different land cover class areas. Land cover class area is the area of a land cover type.

The Percent Landscape of Patch Type is the percentage the landscape comprised of the corresponding patch type. It is the class area (describe above) divided by the total landscape area (i.e. watershed.)

The Mean Patch Size was calculated by dividing the class area for each land cover type by the number of patches of that cover type. This metric provides information on the average size of cover type patches within the watersheds. If larger patches are being fragmented into smaller patches this will be manifest in a general decrease in mean patch size.

The FRAGSTATS output generated patch specific data for each land use type in a watershed over the 36 long-term scenarios. Thus, a watershed with 20 land use classes (from WV Gap data) would have 720 results for each scenario (36 X 20 = 720). Patch analysis using FRAGSTATS was time consuming and generated 14 patch specific metrics for each watershed. Therefore, patch analysis was only run on those watersheds that exhibited major changes in the other metrics and the metric output was truncated to the three metrics that appeared to yield the most important data. Eight of the 63 watersheds were included in the FRAGSTATS analysis of land use patches. Three metric results, the number of patches, percent of the landscape, and mean patch size were used.

The number of patches within a watershed was calculated for each of the 36 long-term scenarios by summing the total number of patches of all of the land class types within the watershed under each scenario. FRAGSTATS calculates the total number of patches of each particular land class in each watershed. Percent of the landscape is also calculated by FRAGSTATS for each land class type in the watershed. This analysis was merely the graphing of the FRAGSTATS results. Mean patch size was calculated by dividing the land class area in a watershed by the number of patches of that class in the watershed.

III. RESULTS

A. MINING SURFACE AREA METRIC RESULTS

1. Permit Area

The permit area from mountaintop mining in the study area from the last ten years is 403,810 acres. If mining trends are consistent, an additional permit area of 403,810 acres will occur in the next ten years. Of the four states in the study area, Kentucky has the greatest permit area with 271,972 acres of mining projected for a ten year period. This permit area is derived by multiplying the acreage based on four years of permit data by a multiplier to generate a ten year number comparable with the other states (108,789 x 2.5). West Virginia, Virginia, and Tennessee permit areas are 90,104 acres, 32,325 acres, and 9,409 acres, respectively. Figure III.A-1 presents the locations of the permits in the study area.

2. Mine Data Ratios

A typical mountaintop mine site is divided into development areas, production areas, support areas, reclamation areas, and valley fills. The mineral extraction area consists of the development and production areas. In West Virginia, the potentially adverse impact of mountaintop mining is 90,104 acres. Of this, the total mineral extraction area equals 51,382 acres while the total valley fill area equals 19,486 acres. The remaining 19,236 acres constitutes auxiliary areas such as office buildings, infrastructure, etc. Figure III.A-2 presents a typical mountaintop mine layout depicting the permit area, production areas and valley fills. The mine data ratios indicate that the permit area is twice as large as the mine extraction area and the mine extraction area is almost twice the acreage of the valley fills.

Mine data ratios from the West Virginia portion of the study area are:

Valley fill : Mine extraction area = 0.4

Valley fill : Mine permit area = 0.2

Mine extraction area : Mine permit area = 0.5

B. AQUATIC METRIC RESULTS

1. Calculated Stream Length

The stream lengths for the Kentucky, Virginia, Tennessee and West Virginia portion of the study area based on the synthetic stream network described in section II. B are as follows. These stream lengths characterize the study area prior to overlaying the mine permits.

Table III.B-1 Miles of Stream in the Synthetic Stream Network

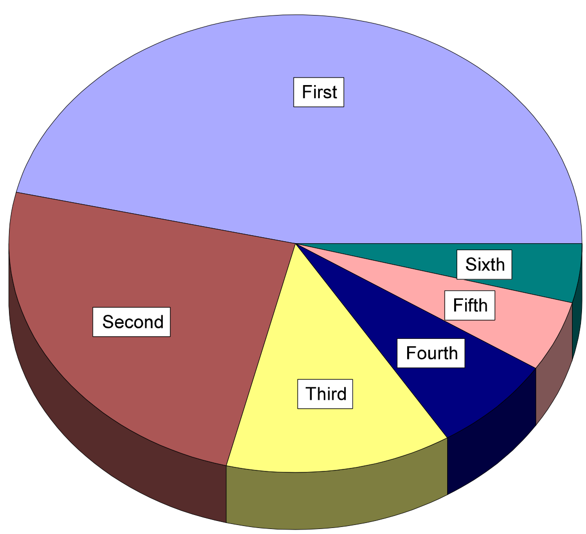
State	**Miles of Stream within Study Area Portion of State**
Kentucky	34,468
Tennessee	5,505
Virginia	7,015
West Virginia	12,010
Entire Study Area	58,998

Total stream length for the approximate 12 million acre study area is 58,998 miles. The order of streams found in the study area include first to sixth order streams. Identification and calculation of stream length by order was not performed in this study. However; a previous analysis (Gannett Fleming 2002) calculated the percent of first through sixth order streams in the West Virginia portion of the study area. This prior identification and calculation of stream orders provides an indication that over half of the stream length in the study area is comprised of first and second order streams. The percent of streams classified by order for the West Virginia portion of the study area are summarized below.

Table III.B-2 Percent of Streams within Different Stream Orders

Stream Order	Percent of Total Stream Length In the WV portion of study area
First	47%
Second	25%
Third	13%
Fourth	7%
Fifth	5%
Sixth	4%

Figure III.B-1 Percent of Streams within Different Stream Orders



2. Aquatic Direct Impacts

Based on permits issued in the last ten years and an assumption of similar permits in the next ten years, aquatic direct impacts to 1, 208 miles of study area stream is estimated. The aquatic metrics include the miles of direct stream impact per state portion of the study area and for the entire study area. Because the calculation of miles of direct stream impact is based on the stream network used, percent of direct stream impact is also a metric. The percent of direct stream impact per state portion of the study area and for the entire study area is calculated. Additional metrices were calculated for the West Virginia portion of the study area because the digital permit data included consistent attribution of the mineral extraction and valley fill areas within the permit area.

Potential impacts to aquatic habitats were evaluated using the metric for direct impacts to stream length and percent of stream directly impacted. Direct impacts are defined as the areas where the permit polygons overlapped the synthetic stream network. The direct impacts reflect surface mining impacts including valley filling, backfilling, and other surface mining impacts that would directly destroy the stream.

Table III.B-3 Miles of Direct Stream Impact

State	Miles of Direct Stream Impact within Study Area Portion of State Based on Permit Area	Percent Impact
Kentucky	730	2.12%
Tennessee	20	0.36 %
Virginia	151	2.10 %
West Virginia	307	2.55 %
Entire Study	1,208	2.05 % of study area streams

Additional results are available for the West Virginia portion of the study area. The digital permit data for West Virginia allowed calculation of the direct stream impacts from mineral extraction area and from valley fill area. These results are as follows.

Table III.B-4 Miles of Direct Stream Impact Per Mineral Extraction and Valley Fill Areas

	Miles of Direct Stream Impact within West Virginia Portion of Study Area	Percent Impact
Mineral Extraction Area	50.43	0.42 %
Valley Fill	156.82	1.31 %
Permit Area	307	2.55 %

As can be seen from the table above, an additional 100 miles of direct stream impact is calculated when the entire permit boundary is used as the disturbance area, as opposed to discrete valley fill and mineral extraction polygons. Although direct stream impact could occur from road crossing and ancillary operations outside of the mineral extraction and valley fill areas, calculation of direct stream impacts using the permit area may be an overestimate.

C. TERRESTRIAL METRIC RESULTS

1. Study Area and State Results

a. Forest Loss

The potentially adverse impact of forest loss from mountaintop mining in the study area from the last ten years of permitting is 380,547 acres. The study area contains 11,231,622 acres of forest. This terrestrial impact equates to a 3.4% forest loss in the study area. Of the four states included in the study area, Kentucky is projected to have the greatest potentially adverse impact of forest loss from mountaintop mining with 255,582 acres (4.0%) of forest loss; however, Kentucky also has the greatest acreage within the study area. The Kentucky forest loss is based on four years of permit data multiplied by 2.5 to yield a ten year estimate(102,233 acres x 2.5). Projected forest loss from the other three states in order of potential adverse impact are: West Virginia, 86,587 acres (3.2%); Virginia, 29,224 acres (2.5%); and Tennessee, 9,154 acres (1.0%).

When adding past, present and future terrestrial disturbance, the study area estimated forest impact is 1,408,372 acres which equates to 11.5 % of the study area. This number is derived by adding grassland as an indicator of past mining, barren land classification, forest lost from the last ten years of surface mine permits and a projection of future forest loss that equates to the last ten years.

b. Non-forest Land Cover Class Change

Forests occupy 92.1% of the study area. Therefore, the greatest potential adverse impact from mountaintop mining is to the forest cover classes. Table III.C-1 summarizes the impacts to all non-forest land cover classes for each state and for the entire study area. In general, the potential adverse impacts for non-forest land cover classes are consistent among each state.

High intensity residential is the only land cover class with no projected impact in the four-state study area. Urban/recreational grasses and emergent herbaceous wetlands are projected to have negligible potential adverse impacts in the study area. Transitional lands and the pasture/hay cover class exhibit the greatest potential adverse impact of the non-forest land cover classes with projected losses of 1,986 acres and 999 acres, respectively. The greatest net change is an increase of 231,177 acres in the surface mining/quarries/gravel pits cover class. This net change takes into account the acres of remining (surface mining/quarries/gravel pits landcover acres in permit polygons). The acres of remining are 4,922 in Kentucky; 16 in Tennessee; 1,849 in Virginia; and 2,664 in West Virginia.

Grasslands (pasture/hay and transitional) are expected to increase as mine sites move to the reclamation phase. This trend is not depicted in the table.

Table III.C-1
Non-Forest Land Cover Class Impacts (acres)

Kentucky Portion of the Study Area	Pre-Impact (NLCD)	Condition from 4 yrs of Issued Permits	Difference
Open Water (ac)	43,914	43,731	-182
Low Intensity Residential (ac)	23,674	23,628	-46
High Intensity Residential (ac)	5,459	5,459	0
Commercial/Industrial/Transportation (ac)	24,673	24,526	-147
Surface Mining/Quarries/Gravel Pits (ac)	37,710	141,577	103,867
Transitional (ac)	17,133	16,363	-770
Pasture / Hay (ac)	251,470	251,051	-419
Row Crops (ac)	65,866	65,798	-68
Urban/Recreational Grasses (ac)	9,410	9,408	-2
Emergent Herbaceous Wetlands (ac)	1,210	1,210	0

Table III.C-1 continued

Tennessee Portion of the Study Area	Pre-Impact (NLCD)	Condition from 10 yrs of Issued Permits	Difference
Open Water (ac)	12,472	12,454	-18
Low Intensity Residential (ac)	10,771	10,769	-2
High Intensity Residential (ac)	1,471	1,471	0
Commercial/Industrial/Transportation (ac)	6,185	6,166	-19
Surface Mining/Quarries/Gravel Pits (ac)	1,208	10,601	9,393
Transitional (ac)	3,059	2,897	-162
Pasture / Hay (ac)	56,114	56,083	-31
Row Crops (ac)	15,358	15,350	-8
Urban/Recreational Grasses (ac)	6,297	6,297	0
Emergent Herbaceous Wetlands (ac)	146	146	0
Virginia Portion of the Study Area	Pre-Impact (NLCD)	Condition from 10 yrs of Issued Permits	Difference
Open Water (ac)	4,790	4,672	-118
Low Intensity Residential (ac)	10,484	10,473	-11
High Intensity Residential (ac)	133	133	0
Commercial/Industrial/Transportation (ac)	4,749	4,729	-20
Surface Mining/Quarries/Gravel Pits (ac)	18,981	49,458	30,477
Transitional (ac)	11,592	10,896	-696
Pasture / Hay (ac)	117,519	117,224	-295
Row Crops (ac)	13,738	13,629	-109
Urban/Recreational Grasses (ac)	182	182	0
Emergent Herbaceous Wetlands (ac)	316	311	5

Table III.C-1 continued

West Virginia Portion of the Study Area	Pre-Impact (NLCD)	Condition from 10 yrs of Issued Permits	Difference
Open Water (ac)	16,622	16,607	-15
Low Intensity Residential (ac)	16,110	16,079	-31
High Intensity Residential (ac)	86	86	0
Commercial/Industrial/Transportation (ac)	9,310	9,275	-35
Surface Mining/Quarries/Gravel Pits (ac)	45,715	133,155	87,440
Transitional (ac)	19,441	19,083	-358
Pasture / Hay (ac)	67,335	67,081	-254
Row Crops (ac)	17,048	16,914	-134
Urban/Recreational Grasses (ac)	128	128	0
Emergent Herbaceous Wetlands (ac)	1,383	1,383	0
Entire Study Area	Pre-Impact (NLCD)	Condition from Issued Permits	Difference
Open Water (ac)	77,798	77,464	-334
Low Intensity Residential (ac)	61,039	60,949	-90
High Intensity Residential (ac)	7,149	7,149	0
Commercial/Industrial/Transportation (ac)	44,917	44,696	-221
Surface Mining/Quarries/Gravel Pits (ac)	103,614	334,791	231,177
Transitional (ac)	51,225	49,239	-1,986
Pasture / Hay (ac)	492,438	491,439	-999
Row Crops (ac)	112,010	111,691	-319
Urban/Recreational Grasses (ac)	16,017	16,015	-2
Emergent Herbaceous Wetlands (ac)	3,055	3,050	-5

c. Grasslands as Indicators of Past Mining Impacts

Grasslands are not common natural habitats in the West Virginia portion of the study area (Straughsbaugh and Core, 1997). It can be assumed that natural grasslands are uncommon habitat throughout the four-state study area, in particular in the steep mountainous portions of the study area like West Virginia and Kentucky. The NLCD indicates that there are 543,663 acres of grasslands (transitional and pasture/hay land cover classes) in the four-state study area. Much of the present grasslands in the study area could be attributed to past mining impacts.

The NLCD indicate that Kentucky has historically undergone the greatest potential adverse impact from mining with 268,603 acres of grasslands. Grasslands equal 129,110 acres in Virginia, 86,777 acres West Virginia, and 59,173 acres in Tennessee. There is a low likelihood that all of the grasslands of the study area can be attributed to mining. However, this acreage for West Virginia is supported by a separate study which estimated 244,000 acres of West Virginia has been disturbed by past or current mining (Yuill, 2002). For further extrapolation on this subject please refer to IV. Uncertainty Section of this report.

2. West Virginia Specific Results

a. Forest Loss

Total forest area of the West Virginia portion of the study area is 2,703,677 acres. The potentially adverse impact of mountaintop mining in West Virginia is summarized below based on specific mining disturbance activities:

Forest loss from mine permit areas = 86,587 ac (3.2%)

Forest loss from mineral extraction areas = 45,544 ac (1.7%)

Forest loss from valley fill areas = 18,338 ac (0.7%)

Forest loss from auxiliary areas = 22,705 ac (0.8%)

b. Impacts to Riparian Habitats

The projected riparian habitat potential adverse impact in the West Virginia portion of the study area total 7,591 acres of an existing 236,843 acres (WV GAP Dataset). This equates to a 3.2% loss in this habitat type in the West Virginia portion of the study area. Approximately 55% of the potentially adverse impacts occur in forested headwater (1^{st} and 2^{nd} order Strahler streams) riparian areas (3,233 ac) and forested small stream (3^{rd} and 4^{th} order Strahler streams) riparian areas (913 ac). There is a high likelihood that these impacts will occur because they are inherently associated with valley fill activities due to this type habitat's position on the landscape. This analysis used the 60% complete permit dataset, therefore, potentially adverse impacts may be underestimations.

c. Potential Ecological Condition

Potential ecological condition (PEC) is a metric designed to determine the ecological condition of a particular landscape unit. Generally, PEC is evaluated at the watershed level. Figure III.C-1 shows the positive relationship between PEC and forest cover using data from the 63 watersheds in the West Virginia portion of the study area.

Using the relationship represented in Figure III.C-1 the PEC of the study area can be calculated for the existing condition (pre-impact), the issued permit condition, and the future projected condition. These conditions are represented on the figure with dashed lines. PEC of the study area under the pre-impact condition is near 1.7 units. Under the permit issued condition PEC scores have the potential adverse impact of dropping to near 1.65 units. The projected future condition could yield a potential adverse impact of a drop in PEC score for the study area to about 1.59 units.

It should be noted that although forest cover is a large determinant in the calculation of PEC, other land use variables also go into the variable (refer to II. Methodology for description of PEC calculation). The values represented in Figure III.C-1 are approximations; however, due to the strong relationship between forest cover and PEC there is a high likelihood that these approximations are accurate.

d. Forest Edge

Forest loss from mountaintop mining in the West Virginia portion of the study area has the potential of creating 2.7% more edge habitat. A total of 17,477 more edge pixels are in the West Virginia portion of the study area after the 60% complete permit dataset is applied to the pre-impact WV GAP dataset. This potentially adverse impact has a high likelihood of occurrence. This increase in edge habitat is an underestimation since the value was calculated using the 60% complete permit dataset.

e. Number of Patches

There area 100,392 pre-impact land class patches in the West Virginia portion of the study area (WV GAP Dataset). When the 60% complete permit data is applied to the WV GAP land cover dataset the number of land class patches increases to 139,689. This is equates to an approximately 40% increase in the number of land class patches which implies an increase in fragmentation of the natural environment. This potentially adverse impact has a high likelihood of occurrence and is an underestimation especially since the result was generated from 60% of the permit data set.

f. Mean Patch Size

Mean patch size in the West Virginia portion of the study area is 24.64 acres (WV GAP Dataset) before the mine permit dataset is applied. Application of the 60% complete permit dataset to the WV GAP land cover dataset yields a mean patch size of 14.33 acres. This reduction in the average size of land class patches implies fragmentation of the natural environmental. The potentially adverse impact of fragmenting the natural environment has a high likelihood of occurrence especially since this decreased is biased high because the permit dataset used was only 60% complete.

g. Percent of the Landscape

The percent of the landscape in the West Virginia portion of the study area that each land class patch type occupies is presented in Table III.C-2. Table III.C-2 includes the percent of the landscape of each land class patch type using the WV GAP Dataset prior to application of the 60% complete permit dataset. The greatest change is in the mining - barren class patch type which shows a 1.9% increase in area following application of the permit dataset. The greatest potential adverse impact is experienced by the diverse mesophytic forest type with a reduction in area of 1.3%.

Table III.C-2
Land Class Patch Type Percent of Landscape, WV

Land Class Patch Type	Percent of the Landscape	
	Pre-Impact (WV GAP Dataset)	Condition from 10 yrs of Issued Permits
Shrubland	1.0	0.9
Woodland	0.2	0.2
Water	1.0	1.0
Highway	<0.1	<0.1
Powerlines	0.3	0.3
Populated	0.2	0.2
Urban (all 3 types)	1.2	1.2
Rowcrop - Ag.	<0.1	<0.1
Pasture - Grassland	3.2	3.5
Mining - Barren	2.6	4.5
Planted Grass	<0.1	<0.1
Conifer Plantation	<0.1	<0.1
Floodplain Forest	0.6	0.6
Forested Wetlands	<0.1	<0.1
Shrub Wetlands	<0.1	<0.1
Herbaceous Wetlands	<0.1	<0.1
Cove Hardwoods	11.7	11.3
Diverse Mesophytic Forest	61.6	60.3
Hardwood - Conifer Forest	1.0	1.0
Oak Forest	6.4	6.3
Mtn. Hardwood Forest	8.6	8.4
Mtn. Hardwood - Conifer Forest	<0.1	<0.1
Mt. Conifer Forest	<0.1	<0.1

IV. UNCERTAINTY SECTION

A. AQUATIC IMPACTS

1. Direct Stream Loss

a. Permit Boundaries

Calculation of direct stream loss based on the entire permit area may overestimate actual direct impact. As can be seen from the West Virginia specific analysis, an additional 100 miles of direct stream impact is calculated when the permit area is used as opposed to a sum of the direct impact based on valley fill area and extraction area. This auxiliary area is occupied by support areas, erosion and sedimentation control facilities haul roads and areas included within the permit because of geometry but not disturbed by mining activities. Direct impacts to streams could occur from activity within the auxiliary area such as sediment ponds and haul roads. The sum of these auxiliary areas is generally small relative to the entire permit area; however, this could overestimate the direct stream loss.

b. Stream Network

The miles of stream is calculated based on a given stream network. Different stream lengths result when different measuring sticks are used. The calculated miles of stream differ between a synthetic stream network and if one were to calculate the miles of stream based on USGS topographic maps. Also, there can be length differences between synthetic stream networks generated in slightly different ways or quantified in slightly different ways because the stream length is greater when greater stream sinuosity. Therefore, there is uncertainty in the miles of direct stream impacts. There is less uncertainty in the percent of direct stream impacts.

The GIS stream network was generated from DEM data using standard ARC Info commands. The streams are "synthetic" in that they were not generated by conversion of existing maps, such as orthophotographs or USGS 7.5' quad sheets, into digital format. Rather, they were generated using a digital elevation model (DEM). A DEM is a digital representation of the earth's surface based on a regular series of sample elevation points organized in a 30x30 meter grid. DEM's can be used to model the direction of water flow and accumulation of flow.

For the data used in the cumulative impact study a contributing area of 30 acres was selected to generate a stream. There is some uncertainty is this selection given that permits in Kentucky have indicated perennial streams in watersheds smaller than 10 acres. Therefore; the synthetic stream network may underestimate stream length.

B. TERRESTRIAL IMPACTS

1. Forest Loss

a. Permit Boundaries

The forest loss was calculated based on permit boundaries. As can be seen from the West Virginia specific analysis, 0.8% of the forest loss was due to auxiliary areas (outside of the mineral extraction and valley fill areas). It is an overestimate to assume that the entire area within the permit boundary will be disturbed. Also, mine areas and fills on permit application maps are often altered during the life of a mine; therefore, the extent of mine extraction area or valley fill used in this study has uncertainty.

b. Kentucky Permit Data

Mine permit polygons in Kentucky were based upon four years of mining permits. Since the other three states had permit data for a ten year time period the Kentucky Permit area and forest loss were multiplied by 2.5 to approximate mine disturbances in a ten year time frame. This adjustment for Kentucky has no spatial placement. There is uncertainty in what land cover type will be disturbed by the actual mines. Kentucky presently is 92.8% forested (NLCD). This suggests that there is a high likelihood that the forest land cover will incur the projected potential adverse impact.

Multiplying the four year permit data by 2.5 to approximate ten years of mining Permit also assumes that mining in Kentucky will continue at the same rate for the last six years of the projection. This also leads to some uncertainty in the data.

c. Timber Harvesting

Mountaintop mining is not the only activity affecting the landscape in the watersheds studied. Forest harvesting is widespread. The wood products industry plays an important role in West Virginia's economy accounting for 11.2% of the state's manufacturing employment (this figure excludes furniture and paper.) The economic importance of this industry is growing . Greenstreet and Cardwell (1997) reported a 40% increase in payroll employment between 1980 and 1995. Much of West Virginia's forests are single cohort stands of merchantable size containing high value species such as oaks, black cherry, yellow-poplar, sugar maple, and white ash. 66% of the state's forests are owned by non-industrial forest land owners, 24% are owned by corporations, and just 6% are publicly owned (Birch, 1996.) Between 1975 and 1989 the percentage of private forest land owners planning to harvests timber rose from 8% to 35% (Birch and Kingsley, 1978; DiGiovanni, 1990 as reported by Fajvan et al., 1998)

In West Virginia the most prominent harvest technique is diameter limit cutting (WV Asst. State Forester, personal communication.) This method selects trees based on stem diameter. For instance all merchantable trees greater than 12" diameter are removed. As large, high value species are disproportionately removed from the stand, species composition shifts to less desirable species such as red maple. Decreases in average stand diameter occur as well as changes in stand density and structure (Fajvan et al., 1998.) Oaks and hickories are highly valued commercially however they also provide an important habitat component to many species of wildlife. With fewer mast producing trees in the residual stands some wildlife populations may experience declines. From an economic standpoint potential future stand value may be decreased. According to Dwyer and Kurtz (1991) "…all too often [diameter limit harvesting] is used as an expedient means to liquidate the future stock of potentially high quality timber supply to improve short-term returns to the purchaser." In sum, diameter limit harvesting is widespread and it has ecological and economic impacts that may combine with impacts from mountaintop mining to exacerbate cumulative effects on the environment and local communities.

d. Temporal Misrepresentations

Forests are the post-mining land use on many of the mined sites used in this analysis. Forest regeneration on mined sites was not considered in the analysis of forest loss from the issued permits or for the projected future condition. Thus, future conditions may have forests on some of the current mine permit areas and this is not accounted for in the analysis. This suggests that forest loss has been overestimated to some extent. Handel (2001) showed that forest regeneration on mined sites is slow; therefore, the likelihood that the projected potential adverse impact to forests will occur is still relatively high.

2. Non-forest Land Cover Class Change

a. Underestimations Due to Scale

The potential adverse impacts to non-forested land cover classes could be grossly underestimated for land cover classes that are common at a small scale. For example, there are probably many home sites that would classify as low intensity residential that are undetectable and therefore unmapped in the National Land Cover Dataset because they are located within a broader land cover type like the deciduous forest. Urban/recreational grasses and emergent herbaceous wetlands are two other land cover that may be under-represented due to this matter of scale.

b. Temporal Misrepresentations

The potential adverse impacts to the transitional and pasture/hay land cover classes may be underestimated due to difficulties projecting these land cover classes on a temporal scale. Many of the mine sites that appear in the pre-impact condition will be reclaimed to grasslands in the near future. This reclamation is not accounted for when projecting potential adverse impacts from the permit data or when projecting the future condition. In the same respect, the surface mining/quarries/gravel pits may be overestimated in the permit condition and projected future condition.

c. Other Land Use Changes

Other land use changes like timber harvesting, commercial development, residential development, etc. are not projected in this analysis. The lack of these other land use changes should be considered when evaluating the projected potential adverse impact from mining under the permit condition and the projected future condition. Any where in this report where a percent land cover is change is noted in this report the reader should consider there is potential for other land use changes to alter the recorded percent. For this reason, in this report potential adverse impacts were recorded as an area (ac) impact when possible.

3. Grasslands as Indicators of Past Mining Impacts

The assumption that all grasslands (pasture/hay and transitional cover classes) in the study area are indicators of historic mining results in an overestimation of past mining impacts. Literature review does indicate that natural grasslands are uncommon in the study area; however, there is no way to be certain that all grasslands in the study area are historic mining sites. A more accurate representation may have been to designate all grasslands above a certain coal seem elevation and of a minimum size as grasslands indicating past mining impacts. This exercise was not done due to project schedule constraints.

The reader should be aware that this number is an overestimation of past mining impacts. Abandoned farm sites and herbaceous floodplains are two examples of the grasslands cover that would result in an overestimation with this metric. Yuill (2002), reporting on the West Virginia portion of the study area only, indicated that agriculture decreased from almost a million acres in 1950 to about 246,000 acres presently. These abandoned agricultural lands may now be another land use (i.e. residential, commercial) but some may be transitional lands that are part of the calculation to approximate past mining impacts. However, Yuill (2002) also estimated 244,000 acres of West Virginia has been disturbed by past or current mining by compiling various data sources including land cover categories such as grassland/pasture. The Yuill (2002) study seems to support the use of transitional and pasture/hay land cover classes as indicators of past mining.

4. Impacts to Riparian Habitats

a. Uncertainty in the Data

This metric was calculated from the 60% complete permit dataset. Therefore, the potentially adverse impact that was calculated is an underestimation of the expected. Riparian habitats used in this analysis were those identified in the WV GAP Dataset (refer to Section II. Methodology for specifics). This dataset differs from the WV GAP land use dataset that was used for modeling other impacts and it includes many of the land use classes used in the other analyses. Thus, impacts to riparian habitats presented herein may be expressed as impacts to other patch types (i.e. Diverse mesophytic forest, Floodplain forest) in other places in this document.

b. Problems in Defining Riparian Habitat

Riparian habitats are defined as those habitats located on the banks of a natural watercourse (Stiling, 1996). Larger watercourses have broader, more defined riparian areas. For example, a river flowing through a valley may have a riparian corridor that is hundreds of feet broad on either side. On the other hand, a small headwater stream flowing down a steep-sided valley may have a riparian area of only a few feet broad. Because of this, many of the riparian areas of the study area may be under-represented in the data.

To help appreciate the extent of potential adverse impacts to riparian habitats of the study area the reader should refer to the stream impact results. The direct impacts to first and second order streams also have impacts to riparian habitats that likely are lacking from the data. These potentially adverse impacts probably constitute a very small area and if included would not change the results substantially.

5. Potential Ecological Condition

a. Factors Associated with Calculation and Application

Potential Ecological Condition (PEC) is a value calculated to determine the ecological health of a defined landscape scale, usually the watershed level. This cumulative impact study evaluated potentially adverse impacts on a broader scale (state by state and four-state study area). The detailed West Virginia analysis did provide watershed level PEC results. From these the relationship between PEC and percent forest cover was used to approximate PEC scores at a study area level. These results are by no means an accurate account of PEC of the study area but are presented here to represent the general trend in PEC decline as forest cover declines.

Other factors associated with PEC calculation (refer to II. Methodology) are omitted from the approximation of PEC at the study area level. Since percent forest cover explains most of the variation in PEC value (refer to Figure III.C-1) it is assumed that the approximated PEC values are accurate representations and worthwhile to be used to show a declining trend in PEC value with declining percent forest cover.

b. Lack of Pre-Impact Value

PEC of the study area was not calculated using the pre-impact data. The best approximation of pre-impact PEC of the study area was obtained through a scatter plot of PEC values vs. percent forest cover for the 63 watersheds in the West Virginia portion of the study area (Figure III.C-1). The results do not allow for a true comparison of pre- and post-potential adverse impact of PEC values. As stated above, however, since PEC and percent forest cover are strongly positively related the approximation presented here is worthwhile to be used to show a declining trend in PEC value with declining percent forest cover.

6. Forest Edge

Forest edge was calculated from the 60% complete permit dataset for the West Virginia portion of the study area. For this reason, the forest edge results are likely an underestimation of the potential adverse impact. Another consideration of forest edge is that beyond a certain threshold as forest is loss the ability for forests to have an edge is loss. That is, at some point, the amount of forest edge in a forest that is being continually fragmented, will eventually begin to decrease because there isn’t enough forest to sustain an edge. Graphically it would appear as a bell-shaped curve.

7. Number of Patches, Mean Patch Size, and Percent of the Landscape

Patch metrics (Number of Patches, Mean Patch Size, and Percent of the Landscape) were run on the 60% complete permit dataset resulting in an underestimation of the potentially adverse impacts. The FRAGSTATS software quantified patch metrics within each of the 63 watersheds of the in the West Virginia portion of the study area. This watershed approach differs from most of the metrics presented in this report which are at the state or four-state study area level. To convert the watershed-based results to a result for the West Virginia portion of the study area each of the 63 watersheds results were tallied for each metric.

V. DISCUSSION

A. ECOLOGICAL SIGNIFICANCE OF METRICES ASSOCIATED WITH THE AQUATIC ENVIRONMENT

1. Summary and Discussion of Results of Aquatic Metrices

Direct impacts to 1,208 miles of streams is estimated based on the last 10 years of digital permit data. If mining, permitting and mitigation trends stay the same, an additional thousand miles of direct impacts could occur in the next ten years. The watersheds with the greatest miles of streams impacted and percent of stream length impacted are presented on Figure V.A-1. The majority of the streams directly impacted are headwater streams. Figure V.A-2 presents ranges of miles of direct stream impacts.

2. Consequences of Altering Ecological Processes in Aquatic Systems

a. Considerations in the Cumulative Impact Assessment of Ecological Process Effects

The array of effects that mountaintop mining and valley fill activities may pose can be incredibly complex. Inherent to this complexity is a tendency for these effects to combine with and/or compound one another. In aquatic systems, the adverse effects of mountaintop mining and valley fill activities may combine to create a larger net negative effect than if considered singularly. This is an additive process referred to as a cumulative effect.

Cumulative effects are broadly defined by the Council on Environmental Quality (CEQ) guidelines for implementing the National Environmental Policy Act (NEPA) as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions" (40 CFR 1508.7). Within the context of this cumulative impact study, cumulative impacts were assessed for a 63 watershed area, representing a subset of the entire MTM/VF study area.

An additional component of cumulative effect, are the underlying adverse effects that may compound one another, creating net negative effects of a different, and potentially more intense, nature. This is a multiplicative process referred to as synergism. Cumulative effects within or among watersheds can cause unacceptable changes to downstream aquatic, terrestrial, and human resources. Cumulative impacts from changes in topography and land cover may result in the elimination of large tracts of habitat necessary for native forest-interior species and may result in micro-climatic changes.

The cumulative effects in aquatic ecosystems may not only affect aquatic resources. By their nature, the cumulative effects of mountaintop mining and valley fill activities upon aquatic systems can extend to affect the environmental health of ecosystems outside the aquatic realm. This is due primarily to the extensive and complex interconnectedness between terrestrial and aquatic ecosystems. Physical, chemical, and biological changes to aquatic systems can affect water quality, water quantity, and aquatic life. This in turn may lead to changes in the natural environment such as forest communities (floral and faunal), microhabitats; and rare, threatened and endangered species. These effects may compound further and ultimately affect the human environment.

The cumulative effects analysis of aquatic systems performed in this study focused on direct impact to stream systems through actual loss of stream length. No attempt was made to assess stream length that may become impaired as a result of indirect effects from filling or mining.

It is also necessary to consider the secondary effects of activities associated with mountaintop mining and valley fill activities. Secondary effects are actions which, in this case, are conducted in support of establishing or operating a mine, and are defined by CEQ as those that are "caused by an action and are later in time or farther removed in distance but are still reasonably foreseeable" (40 CFR 1508.80). These activities such as clearing sites, building access or haul roads, and drainage or sediment control systems, can cause alterations in the topography and drainage patterns of mined areas. There are also changes in vegetation and ground cover that are associated with mountaintop mining. The possible cumulative effect from similar or multiple projects has been raised as a concern for analysis in these watersheds. No quantitative evaluation of secondary effects was performed in this cumulative impact study.

b. Ecological Process Effects in Aquatic Systems

This section focuses specifically in the cumulative impacts to headwater streams and their associated watersheds from mining and associated activities. One useful approach to evaluating cumulative impacts focuses on an evaluation of ecological processes. USEPA (1999) lists a total of 10 ecological processes that effectively capture ecosystem functioning and should be evaluated for adverse effects. These processes include:

1. Habitats Critical to Ecological Processes
2. Pattern and Connectivity of Habitat Patches
3. Natural Disturbance Regime
4. Structural Complexity
5. Hydrologic Patterns
6. Nutrient Cycling
7. Purification Services
8. Biotic Interactions
9. Population Dynamics
10. Genetic Diversity

Two of these processes are associated largely with terrestrial systems in the MTM/VF study area. These include pattern and connectivity of habitat patches and natural disturbance regimes. Impacts to these ecological processes have been discussed in terrestrial-related sections of this document. Impacts from MTM/VF activities to the remaining eight ecological processes will be summarized in this section as part of the evaluation of cumulative impacts.

Impacts to ecological processes may result from direct activities or indirectly from alterations resulting from direct activities. This is true both for primary impacts from mining and from secondary impacts which include items such as road building, changes in residential patterns etc. that may occur as a result of the mining activity. The most significant direct impact to headwater stream systems is the direct filling of the steam and watershed during mining activities. Other direct impacts would result from secondary activities such as logging or road building but in terms of total impacts to this ecosystem, impacts from filling would be far more extensive and long lasting. Indirect impacts from filling include impacts that affect the ecological process in the stream system downstream from the filled area. These impacts largely result from direct changes in the stream system's flow regime, thermal regime, water chemistry or sediment load from mining. A cascading series of indirect effects may result from changes to any one ecological process.

Habitats Critical to Ecological Processes

At the level of a landscape or region, certain natural habitat types are especially important for the ecological functioning or species diversity of the ecosystem. Unusual climatic or edaphic (soil-based) conditions may create local biodiversity hotspots or disproportionally support ecological processes such as hydrologic patterns, nutrient cycling, and structural complexity. For these reasons, preservation of specific habitats (usually the remaining natural areas within the landscape) should be a priority (USEPA, 1999).

Within the landscape, certain habitats disproportionately contribute to ecosystem functioning. In general, these are the remaining natural areas, especially those that integrate the flows of water, nutrients, energy, and biota through the watershed or region (Polunin and Worthington, 1990). Headwater stream systems naturally provide these listed functions. (USFWS, 1999).

Headwater streams are destroyed by filling. The fisheries and streams technical studies in support of the MTM/VF EIS support that the functions of these systems may be impacted for considerable downstream distances by upstream fills. Cumulatively, many activities, in addition to filling, resulting from mine construction may result in destruction or degradation of the headwater stream systems. Although data are lacking on the magnitude of mining impacts compared to other major alterations in land use such as forestry, the permanent nature of filling would suggest that MTM/VF impacts of critical headwater stream systems constitute one of the most major threats to this system in the study area.

Structural Complexity

At the local scale, ecosystems possess a natural complexity of physical features that provides for a greater variety of niches and more intricate interactions among species. Local structural complexity increases with more snags in the forest, and more woody debris in the stream. At other scales, spatial heterogeneity is equally important, affecting a wide range of ecological processes from predator-prey interactions to energy transfer among ecosystems (USEPA, 1999). Considerable experimental evidence supports the concept that physical structure may prevent generalist foragers from fully exploiting resources and thus promote the coexistence of more species (e.g., Werner, 1984). Simply put, complex habitats accommodate more species because they create more ways for species to survive (Norse, 1990).

Headwater stream systems are known to be structurally complex. The structural complexity of headwater streams may be negatively impacted by several indirect effects from MTM/VF. Stream sections downstream from fills may be subjected to increased sedimentation from improper placement of sedimentation ponds, sedimentation pond failure or from post mining run off. Sedimentation may also result from runoff from areas being logged prior to mining. Sedimentation may fill pool areas and smother riffles and snags, decreasing the structural complexity of the stream.

Technical studies performed for the MTM/VF EIS indicate that both stream flow and stream temperature may become more constant in streams sections downstream from fill. Although these changes may not impact the physical complexity of streams, there may be subtle decreases in availability of niches that occur from decreasing the normal flow and thermal fluctuations inherent in headwater stream systems.

Timber harvesting or tree removal is generally performed prior to mining. Timber harvesting may be limited to the area of coal extraction, or may extend down the watershed from the anticipated toe of fill. This activity would impact the leaves and woody material available for deposition into a stream. A decrease in these materials would impact the stream's structural complexity by reducing the material available for forming leaf packs, snags, or other woody-material related stream structures. Woody material in these systems is also responsible for retaining small volumes of water into micro-pools which represent an additional source of structural complexity (Wallace, 1992).

Several of the impact factors mentioned including sedimentation and reductions in the inputs of leaves and woody material would not be limited to mining impacts only. These types of impacts would also occur from other activities such as forestry.

Hydrologic Patterns

Ecosystems possess natural hydrologic patterns that provide water for organisms and physical structure for habitats. This cycle of water is also the vehicle for the transfer of abiotic and biotic materials through the ecosystem. The natural hydrologic patterns of an ecosystem include the magnitude, frequency, duration, timing, and rate of change (flashiness) of water flow.

The range of hydrologic variability in streamflow quantity and timing can be thought of as a "master variable" affecting biodiversity and ecological integrity in riverine systems (USEPA, 1999). The natural flow of a river varies on a time scale of days, seasons, years and longer (Poff et al. 1997).

There are five critical components of the flow regime (Poff and Ward, 1989, Richter et al., 1996):

- Magnitude
- Frequency
- Duration
- Timing
- Rate of change (flashiness) of hydrologic conditions

These components interact to maintain the dynamics of in-channel and floodplain habitats that are essential to aquatic and riparian species (Poff et al., 1997).

Hydrologic modeling studies performed for the MTM/VF EIS found that peak storm water flows are slightly higher during and after mining. Hydrologic results from a separate field study indicate that fills tend to increase the base flow of the stream and decrease the peak flow during a storm event. Water temperature in streams in filled watersheds was less variable than in unfilled watersheds.

These types of impacts appear to be unique to MTM/VF activity in the study area. Other activities which might affect hydrologic patterns, such as agricultural practices or water withdrawals, are not major activities in the study area. Alterations in hydrologic patterns may have further impacts on other ecological processes and are discussed under those processes. For both direct and indirect impacts to ecological processes resulting from alterations in hydrologic patterns, MTM/VF would appear to be the major impact producing activity in the study area.

Nutrient Cycling

Ecosystems have evolved efficient mechanisms for cycling nutrients, which combined with sunlight and water determine the productivity of the systems. The natural flow or organisms, energy, and nutrients is essential for maintaining the trophic structure and resiliency of the ecosystem. Reduction or augmentation of nutrient inputs to ecosystems can drastically alter these trophic interactions and ultimately the quality of the environment. The input and assimilation of nitrogen is the most common measure of nutrient cycling, but the dynamics of other essential compounds are also important.

Nutrient cycles are the processes by which elements such as nitrogen, phosphorus, and carbon move through an ecosystem. This cycling is critical to the functioning of ecosystems; otherwise essential elements and nutrients would continue on a relentless flow downhill, depleting ecosystems uphill (Noss and Cooperrider, 1994). But terrestrial and aquatic systems have developed mechanisms that slow the movement of water, nutrients, and energy to the sea. Vegetation of all types intercepts nutrient-rich waters and bind materials in place. Anadromous fishes and other migrating species move major amounts of biomass and minerals upstream, but the role of animals in moving nutrients uphill has received relatively little study.

Trophic interactions within ecosystems (e.g., the food chain of plant-herbivore-carnivore) are the most visible part of the cycling of energy and nutrient within ecosystems. Changes in the input or export of nutrients within ecosystems can affect the status of these trophic levels and can have ramifications for biotic interactions as well as ecosystem functioning. Less obviously, decomposers (such as invertebrates and microorganisms) serve the critical role of recycling dead material at each stage of the nutrient cycle and ultimately supply the soil nutrients that feed the plants that capture the sun's energy. Many small streams have a nutrient base of leaves and downed wood that feeds insects shredders and collectors. When this nutrient base is diminished by the removal of downed wood or logging of forests, production rapidly declines.

Impacts from MTM/VF activities to the ability of headwater streams to maintain their nutrient cycling function are of great concern. The loss of the nutrient cycling function of the portion of headwater streams from direct filling may represent a substantial loss of energy to the entire aquatic system within and beyond the watershed containing the fill. This direct loss may be compounded by the further impairment of the aquatic community downstream from fills. Studies seem to suggest that the impacts to the aquatic community downstream from fills may result from water quality impacts due to filling which may be extremely difficult or impossible to correct.

The combination of the direct fill impacts which decrease nutrient cycling and indirect impacts through impairment of the aquatic community downstream from fills may result in a substantial impact to the nutrient cycling function in headwater streams. This impact has proven difficult to study directly. There is ongoing debate among regulators and scientists on the best way to collect quantitative evidence for the possible occurrence and the severity of the potential impact to nutrient cycling functions of headwater streams. Although this impact is difficult to demonstrate empirically, substantial evidence exists in the primary literature demonstrating that shifts in the aquatic community structure impact the ability of streams to process leaves and woody material, thereby decreasing the input of energy to downstream areas. This evidence supports ongoing concerns over impacts from MTM/VF to the nutrient cycling process.

Other activities, such as logging, also pose potential threats to the nutrient cycling function of headwater streams in the study area. However, the permanent nature of filling compared to the more temporary and possibly more manageable impacts from forestry, would suggest that MTM/VF impacts of to the nutrient cycling function of headwater stream systems constitute one of the most major threats to this system in the study area.

Purification Services

Ecosystems naturally purify the air and water. They also detoxify and decompose both natural and manmade wastes. Purification processes are necessary for the normal functioning of ecosystems; they break down harmful concentrations of toxic materials and refertilize soils and sediments through the action of microbes and other organisms. The capacity of ecosystems to assimilate and recycle waste material depends on physical, chemical, and biological mechanisms; this capacity may be exceeded by anthropogenic inputs depending on system-specific conditions.

Headwater stream systems do not have a tremendous capacity to provide purification services. However, although this ecological process is not one which requires protection for headwater streams, the absence of streams to provide this service reflects the sensitivity of this system to inputs of a variety of toxic materials. Surface mining releases a variety of potentially toxic materials into the environment including metals and mineral constituents such as sulfates which may act by altering physical characteristics of water (e.g. pH or specific conductance). Headwater streams, with their innately limited buffering capacity and lack of ability to sequester and precipitate out contaminants, tend to be at risk from any input of toxic materials.

In contrast, wetlands are among the most effective ecosystems for removing pollutants and purifying wastes. Wetlands operate through a series of interdependent physical, chemical and biological mechanisms that include sedimentation, adsorption, precipitation and dissolution, filtration, biochemical interactions, volatilization and aerosol formation and infiltration (USEPA, 1999). Constructing wetlands has been suggested as a possible mitigation measure for impacts to headwater streams. While this issue is complex, there may be promise in constructing wetlands in stream channels of streams impacted by MTM/VF or at the toe of fill where groundwater emerges into stream channels to improve the water quality of streams downstream from fill areas. The success of these wetland systems to improve water quality would be highly dependent on the toxicity of the water initially.

Biotic Interactions

The interactions, including the antagonistic and symbiotic interactions, among organisms are some of the most important, but least understood, factors influencing the structure of natural ecosystems. Because these interactions have evolved over long periods of time, the deletion of species from or the addition of species to an ecosystem can dramatically alter its composition, structure, and function.

Biotic interactions that are particularly important in maintaining community structure or ecosystem function are described as “keystone” interactions (USEPA, 1999).

Section I.A. describes biotic interactions common in headwater streams. Other Sections in Chapter I discuss various vertebrate species including birds, salamanders and newts and mammals which require interactions with the aquatic environment in order to maintain their lifecycle. Biotic communities have been demonstrated to occur in the uppermost reaches of watersheds, even in “ephemeral” stream zones which flow only as a result of rain or snow melt. Filling eliminatesl aquatic and aquatic-dependant interactions that would formerly have occurred in the filled area. In areas downstream from fills, changes in the macroinvertebrate and fish communities have been observed. (USEPA, 2000 and Stauffer, 2000). Any change in community composition may potentially have impacts to biotic interactions beyond that measured in the community composition study, but these interactions are often difficult to demonstrate.

Many other impact producing factors in the study area may cause environmental changes that would result in alterations or simplifications in biotic communities and associated biotic interactions. Although data are lacking on the magnitude of mining impacts compared to other major alterations in land use such as forestry, the permanent nature of filling would suggest that MTM/VF impacts to biotic interactions in headwater stream systems, including interactions linking terrestrial biota to the aquatic environment, constitute one of the most major threats to this system in the study area.

Population Dynamics

The population is a critical unit, not only for evolutionary change, but for the functioning of ecosystems. Population numbers alone do not adequately reflect the prospects for species or the continued performance of their ecological role. Information about life history and population dynamics, such as dispersion, fertility, recruitment, and mortality rates, is critical to identifying potential effects on population persistence and ecological processes. Key factor analysis can determine which links in these dynamics primarily affect population success, while population viability analysis can predict the amount and distribution of habitat needed to maintain healthy populations (USEPA, 1999).

When populations are lost, the local adaptations of these populations are lost, the ecosystem functions performed by these populations cease, and ultimately species may go extinct. In general, the risk of losing populations (and with them ecological integrity) is greatest when populations are small, but even large populations may have critical components of their life histories of population cycles that make them especially vulnerable (USEPA, 1999).

Direct and indirect impacts affecting population dynamics are of great concern for the headwater stream systems in the study area. As discussed in Section I.A., these biotic systems are characteristically locations with high numbers of endemic, unique and rare populations of macroinvertebrates, amphibians and fish. These populations tend to be small and highly specialized for life in the headwaters environment. Species with these traits tend to be sensitive to relatively small changes in their environment (Stein et al., 2000). Some species in headwater streams may have distributions limited to only one or several watersheds. With such a small geographic range, fill activities from one mine may impact the entire population.

MTM/VF activities may impact population dynamics through indirect as well as direct impacts. Examples of changes that might occur include the following. Changes in contaminants or in thermal regime may affect survivorship and reproduction. The number of individuals available for recruitment may also decrease. The increase in base flow may eliminate intermittent flow areas which serve as refugia for amphibians from fish. The loss of autochthonous input from concurrent timber harvesting may decrease the habitat types available which may impact reproductive success for some species. Finally, egg mortality may increase from increased sedimentation.

Many other impact producing factors in the study area may cause environmental changes that would result in altered population dynamics and the extirpation of populations of some species. Although data are lacking on the magnitude of mining impacts compared to other major alterations in land use such as forestry, the permanent nature of filling would suggest that MTM/VF impacts to population dynamics in headwater stream systems constitute one of the most potentially adverse threats to this system in the study area.

Genetic Diversity

Diversity at the genetic level underlies the more visible diversity of life that we see expressed in individuals, populations, and species. Over evolutionary time, the genetic diversity of individuals within and among populations of species contributes to the complex interplay of biological and nonbiological components of ecosystems. The preservation of genetic diversity is critical to maintaining a reservoir of evolutionary potential for adaptation to future stresses.

Genetic diversity originates at the molecular level and is the result of the accumulation of mutations, many of which have been molded by natural selection. The genetic variants found in nature are integrated not only into the physiological and biochemical functions of the organism, but also into the ecological framework of the species. The genetic diversity of a species is a resource that cannot be replaced (Solbrig, 1991). Genetic diversity enables a population to respond to natural selection, helping it adapt to changes in selective regimes. Evidence indicates that a reduction of genetic diversity may increase the probability of extinction in populations.

Many of the factors that would affect genetic diversity have been discussed for population dynamics. Extirpating populations as well as species would result in decreases in genetic diversity in the study area. Direct filling of streams reduces the numbers of individuals of rare and endemic species thereby reducing its genetic diversity or even causing it to become extinct. Indirect impacts from mining through alterations in water chemistry, stream flow or the aquatic thermal regime may also negatively impact populations reducing genetic diversity.

The southern Appalachians have been identified by the Nature Conservancy as one of the hot spot areas in the United States for rarity and richness (Stein et al., 2000). This region is known to have the highest regional concentration of aquatic biodiversity in the nation. For this reason, it is hypothesized that impacts which result in decreases in genetic diversity, as measured by loss of species, loss of populations or loss of genetic variants, would have a disproportionately large impact on the total aquatic genetic diversity of the nation.

B. ECOLOGICAL SIGNIFICANCE OF METRICS ASSOCIATED WITH THE TERRESTRIAL ENVIRONMENT

1. Ecological Significance of Forest Loss

Based on permits issued in the last ten years and an assumption of similar permits in the next ten years, mountaintop mining has the potential to adversely impact 380,547 acres of forest in the four-state study area. Table V.B-1 outlines the projected terrestrial impacts in the four-state study area. Table V.B-1 projects the future terrestrial condition using the issued permit data and a long-term future projection which is 2X the permit data projection. The data show that forest loss is associated with an increase in the quarry/strip mines/gravel pits land cover type. When adding past, present, and future forest impact; the study area estimated forest impact is 1,408,372 acres. This impact acreage errs toward overestimation as described in the uncertainty section.

Table V.B-1
Predicted Terrestrial Impacts

Kentucky Portion of the Study Area	Baseline Condition (NLCD)	Condition from Issued Permits	Projected Future Condition
Forest Cover (ac) [4 yr permit data x 2.5]	6,400,838	6,145,256	5,889,674
Forest Cover (%) [4 yr permit data x 2.5]	92.8	89.3	85.6
Forest Loss (ac) [4 yr permit data x 2.5]	---	255,582	511,164
Grassland as indicator of past mining impact (ac)	268,603	267,414	---
Quarry/strip mines/gravel pits (ac) [4 yr permit data x 2.5]	37,710	271,972	---
Tennessee Portion of the Study Area	Baseline Condition (NLCD)	Condition from Issued Permits	Projected Future Condition
Forest Cover (ac)	960,455	951,301	942,147
Forest Cover (%)	89.5	88.6	87.8
Forest Loss (ac)	---	9,154	18,308
Grassland as indicator of past mining impact (ac)	59,173	58,980	---
Quarry/strip mines/gravel pits (ac)	1,208	10,601	---
Virginia Portion of the Study Area	Baseline Condition (NLCD)	Condition from Issued Permits	Projected Future Condition
Forest Cover (ac)	1,166,652	1,137,428	1,108,204
Forest Cover (%)	86.5	84.3	82.1
Forest Loss (ac)	---	29,224	58,448
Grassland as indicator of past mining impact (ac)	129,110	128,120	---
Quarry/strip mines/gravel pits (ac)	18,982	49,458	---

Table V.B-1 continued
Predicted Terrestrial Impacts

West Virginia Portion of the Study Area	Baseline Condition (NLCD)	Condition from Issued Permits	Projected Future Condition
Forest Cover (ac)	2,703,677	2,617,065	2,530,478
Forest Cover (%)	93.8	90.6	87.5
Forest Loss (ac)	---	86,587	173,174
Forest Loss from Valley Fills (ac)	---	*18,338*	---
Forest Loss from Mineral Extraction Area (ac)	---	*45,544*	---
Forest Loss from Auxiliary Areas (ac)	---	*22,705*	---
Grassland as indication of past mining impact (ac)	86,777	86,164	---
Quarry/strip mines/gravel pits (ac)	45,715	133,155	---
Entire Study Area	Baseline Condition (NLCD)	Condition from Issued Permits	Projected Future Condition
Forest Cover (ac)	11,231,622	10,844,519	10,457,416
Forest Cover (%)	92.1	88.9	85.7
Forest Loss (ac)	---	380,547	774,206
Grassland as indicator of past mining impact (ac)	543,663	540,678	---
Quarry/strip mines/gravel pits (ac)	103,615	403,810	---

NLCD = National Land Cover Data Set

Figure V.B-1 depicts the 20 watersheds with the most potential adverse impact in terms of forest loss. When this figure is compared to Figure II.A-1 one can see that the Northern Cumberland Mountains Ecological Subregion has the greatest potential adverse impact in terms of forest loss (%). In contrast, Figure V.B-2 depicts watersheds in the four-state study area with less than 87% forest cover. The Northern Cumberland Plateau Ecological Subregion has the most watersheds with less than 87% forest cover under the condition from the issued permits.

a. Uniqueness of Habitats Within the Study Area

The study area is unique in that it contains a diverse flora and fauna with a mixture of northern and southern species. The steep mountain slopes and deep valleys create a unique topography which lends itself to the development of numerous microclimates. These microclimates are in part responsible for the great variety of vegetative communities found within the study area. Each of these vegetative communities provides forage, shelter, and nesting places for reproduction to characteristic wildlife species.

The data suggests that five of the land use / habitat types of the West Virginia portion of the study area undergo considerable changes under the long-term mountaintop mining scenarios. These five habitat types and the species that they support are discussed below.

Diverse Mesophytic Hardwood Forests and Cove Hardwood Forests

Dominant among the land use types in the West Virginia portion of the study area is the diverse mesophytic hardwood forest (61.6%). This forest type is among the most diverse forest type in the southeastern United States, containing more than 30 canopy species (Hinkle et al.,1993). The predominant species in the diverse mesophytic forest type are various maples (*Acer* spp.), yellow poplar (*Liriodendron tulipifera*) and beech (*Fagus grandifolia*); however, dominance is shared by a large number of species including various oaks, hickories (*Carya* spp.), cherry (*Prunus* spp.), and black walnut (*Juglans nigra*), to name but a few. This forest type is characterized by a diverse understory of trees that never attain canopy position such as dogwoods (*Cornus* spp.), magnolias (*Magnolia* spp.), sourwood (*Oxydendrum arboreum*), striped maple (*Acer pennsylvanicum*), and redbud (*Cercis canadensis*). Wildflowers are commonly found in this forest type because of the open canopy in the spring.

The cove hardwoods are a type of mixed mesophytic hardwood forest. They are included here because species common to the cove hardwoods are likely common to the mixed mesophytic hardwood forest type as well due to their spatial relationship. Cove hardwoods are found in ravines, coves and along north-facing slopes. Species composition is generally very diverse with yellow poplar, red oak (*Quercus rubra)*, pin cherry (*P. pennsylvanica*), black cherry (*P. serotina*), paper birch (*Betula papyrifera*), yellow birch (*B. alleghaniensis*), aspen (*Populus* spp.), sugar maple (*A. saccharum*), red maple (*A. rubrum*), and Eastern hemlock (*Tsuga canadensis*). Local species dominance patterns are often small scale with significant species changes over relatively short distances.

Due to the abundance and variety of fruits, seeds, and nuts the diverse mesophytic forest type provides excellent habitat for wildlife and game species alike. Species of birds typically present include the wood thrush (*Hylocichla mustelina*), Acadian flycatcher (*Empidonax virescens*), and blue-gray gnat-catcher (*Polioptila caerulea*). Wildlife species richness of the mixed mesophytic forests of the study area are considered one of the most diverse in the United States (Hinkle et al., 1993).

Mining-Barren Lands

The mining-barren lands patch type includes those areas where mining activities have significant surface expression. Generally, vegetative cover and overburden have been removed to expose deposits of coal, iron-ore, limestone, and other rocks and minerals. Included in this category are inactive coal mines, quarries, gravel pits, etc. that lack sufficient vegetative cover for reclassification in another patch type. Also included are those areas that for one reason or another, human induced or not, are unable to support vegetation. These may be areas with thin soils, or sand or rock covered. For the sake of this report, the increase in mining-barren lands recognized under many of the long-term scenarios is associated entirely with coal mining. Other mining activities in the study area may also lead to an increase in this patch type.

Pasture-Grasslands

The pasture-grasslands land cover type includes pastureland, hay fields, old fields, abandoned farms, and other herbaceous land cover areas (excluding wetlands). This is an important patch type in the study area because many of the mine sites are converted to grasslands post-mining. Grasslands are unique to the study area and historically were sporadic in distribution across West Virginia (Strausbaugh and Core, 1997).

Grasslands provide food and shelter to a variety of wildlife, including game animals such as whitetail deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*). This patch type also provides habitat for a variety of songbirds that are rare in the study area. Included among these are the grasshopper sparrow (*Ammodramus savannarum*), Henslow's sparrow (*A. henslowi*), and the bobolink (*Dolichonyx oryzivorus*), each of which is listed as rare in West Virginia (Wood and Edwards, 2001). These species may be listed as rare because historically their habitat is rare in the state. As this patch type increases in abundance these species may well be removed from the list.

Oak Forests

The oak forest land cover patch occurs throughout much of West Virginia. These areas generally occur on poorer/well-drained soils, ridges, or south and west facing slopes. Dominant species include white oak (*Q. alba*), black oak (*Q. velutina*), chestnut oak (*Q. montana*), and red oak mixed with red maple, yellow poplar, beech, and sugar maple.

Oak forests are important to wildlife because of their production of hard mast. Hard mast includes acorns, walnuts, and other seeds from trees. Many wildlife species feed on acorns throughout the year. Deer and squirrels are well known acorn feeders but even the lesser seen mice and many birds depend on acorns for food throughout the year.

b. Discussion of Wildlife Dependent on Forested Habitats

The WV Gap Dataset indicates that there are 26 distinct land use types in the West Virginia portion of the study area and 16 of these are associated with the terrestrial habitat. The WV Gap data also includes a list of species that are dependent upon each land use type / habitat. Table V.B-2 summarizes the WV Gap data for the terrestrial habitats of the study area.

Table V.B-2
Summary of West Virginia Gap Terrestrial Land Use Data and the Number of Wildlife Species Associated with Each Land Use Class

Land Use Class	**Size (ac)**	**No. of Species Associated with the Land Use Class**		
		Birds	**Mammals**	**Herptiles**
Diverse Mesophytic Hardwood Forests	1,852,790	131	56	57
Oak Forests	193,833	106	54	43
Pasture-Grasslands	97,620	72	44	29
Mountain Hardwood Forests	31,633	114	53	45
Hardwood-Coniferous Forests	864	124	56	46
Cove Hardwoods	350,861	93	45	39
Urban and Populated Lands	44,163	17	6	6
Mining-Barren Lands	78,377	24	6	12
Shrublands	30,196	102	54	33
Woodlands	5,170	54	21	12
Floodplain Forests	17,384	110	53	55
Mountain Coniferous Forests	864	81	49	31
Mountain Hardwood-Coniferous Forests	793	107	52	33
Row Crops-Agriculture	1,638	49	27	15
Conifer Plantations	168	95	53	33
Planted Grass	390	11	5	3

The diverse mesophytic hardwood forest is the dominant habitat type in the West Virginia portion of the study area. Table V.B-2 indicates that as many as 244 vertebrate species occupy the diverse mesophytic hardwood forests of the West Virginia portion of the study area. In general, species found within the diverse mesophytic hardwood forest are found in the other forest types. This is supported by the data presented in Table V.B-3 which lists the number of bird species that each habitat type (patch) shares with the mixed mesophytic hardwood forest patch type. Thus in a broad sense, forest loss in the West Virginia portion of the study area has the potential of directly impacting as many as 244 vertebrate wildlife species.

Table V.B-3
Summary of the Avian Richness
of the West Virginia Portion of the Study Area

WV Gap Habitat Class	Total No. of Avian Species	No. of Avian Species Shared With the Mixed Mesophytic Hardwood Forest
Barren-Mining Lands	24	16
Commercial	17	10
Conifer-Oak Forests	124	117
Conifer Plantations	95	84
Cove Hardwoods	93	93
Floodplain Forests	110	108
Planted Grass	11	6
Grasslands	72	44
Mixed Mesophytic Hardwoods	131	---
Mountain Coniferous	81	71
Mountain Hardwoods	114	114
Mtn. Hardwoods-Coniferous	107	98
Oak Forests	106	105
Orchards	23	21
Pasture	49	30
Palustrine Emergent Wetlands	55	26
Palustrine Forested Wetlands	84	77
Palustrine Open Water	100	70
Palustrine Scrub-Shrub WLs	66	52
Row Crops	49	30
Rural Lands	100	73
Shrublands	102	79
Urban Lands	17	10
Woodlots	54	51

Source: WV Gap Dataset

Wildlife impacts in the West Virginia portion of the study area can be semi-quantified as done above through the application of data available from the WV Gap Dataset. There is a high likelihood that wildlife assemblages in Virginia, Tennessee, and Kentucky run a similar risk of potential adverse impacts on wildlife assemblages as those in West Virginia since the ecological subregions, described previously, do not follow political borders.

c. Important Wildlife That May Serve as Models or Ecological Indicators of Disturbance

Impacts on Forest Interior and Neotropical Migrant Bird Populations

West Virginia has a rich avian fauna with 183 known species of birds (WV Gap data). There are 131 species of birds known to inhabit the mixed mesophytic hardwood forests of the study area (WV Gap data). Table V.B-3 summarizes the avian richness of the study area based on WV Gap habitat and bird occurrence data. The data show that forested habitats of the study area are the most diverse in terms of avian species richness and that shrublands, open water wetlands, and grasslands contain a rich avian assemblage that differs considerably from that of the forests.

Table V.B-4 lists area requirements for the 19 neotropical migrant bird species included in Robbins et al. (1989) study. This table lists the area where the maximum number of individuals is observed and the area where 50% of the maximum number of individuals is observed for each species. Based on these data, 14 of the 19 species require unbroken tracts of forest in excess of 7,413 ac (3,000 ha) for a maximum probability of observation. The black-throated blue warbler (*Dendroica caerulescens*) has the largest area requirement of the birds included in the study. This statement is supported by the 2,471 ac (1,000 ha) area requirement for probability of observation 50% that of the maximum.

Table V.B-4
Forest Area Requirements for 19 Neotropical Migrant Bird Species of the Study Area

Common Name	**Area where probability of observance is maximum (ac)**	**Area where probability of observance is 50% max. (ac)**
Acadian flycatcher	7,413+	37
Great crested flycatcher	178	1
Blue-gray gnatcatcher	7,413+	37
Veery	618	49
Wood thrush	1,235	2
Red-eyed vireo	7,413+	6
Northern parula	7,413+	1,285
Black-throated blue warbler	7,413+	2,471
Cerulean warbler	7,413+	1,730
Black-and-white warbler	7,413+	544
Worm-eating warbler	7,413+	371
Ovenbird	1,112	15
Northern waterthrush	7,413+	494
Louisiana waterthrush	7,413+	865
Kentucky warbler	741	42
Canada warbler	7,413+	988
Summer tanager	7,413+	99
Scarlet tanager	7,413+	30
Rose-breasted Grossbeak	7,413+	2

Adapted from: Robbins et al. (2000)

In general, watershed PEC values throughout the West Virginia portion of the study area, under the issued permit condition, are good or excellent. PEC values range from 0.86 units to 1.93 units with a mean value of 1.57 units (standard deviation 0.20 units). Forty-six of the 63 watersheds have PEC values of 1.62 or greater. This suggests that mountaintop mining alone may not have an adverse impact on the biologic integrity of the West Virginia portion of the study area.

Although the data suggests that ample forest will remain in the West Virginia portion of the study area to maintain relatively high PEC scores, impacts to many forest interior bird species are still likely to occur. Take for example those species with breeding ranges that are restricted to or confined mostly within the study area. Figure V.B-3 illustrates the breeding ranges of three forest interior bird species (Louisiana Waterthrush, Worm-eating Warbler, and Cerulean Warbler) that may be affected by mountaintop mining. The core of each of these species breeding ranges is within the study area. Disturbances associated with mountaintop mining have the potential to adversely impact each of these species breeding ranges. The above mentioned warblers inhabit upland forests while the Louisiana waterthrush inhabits forested riparian habitats. The potential adverse impact of loss of habitat for these species has extreme ecological significance in that habitats required by these species for successful breeding are limited in the eastern United States.

Wood and Edwards (2001) provide evidence that mine sites that were converted to grasslands after mountaintop mining provide habitat for a number of grassland bird species that are listed as “rare” in West Virginia. These species are rare in West Virginia because historically grasslands are rare in the state (Strausbaugh and Core, 1997). Some may argue that providing habitat for species listed as rare is ecologically significant. However, these grassland species have substantial breeding habitat in other parts of the United States. To illustrate this the breeding habitat of four grassland species known to occupy the grasslands of post-mining sites (Dicksissel, Horned Lark, Eastern Meadow Lark, Grasshopper Sparrow) is depicted on Figure V.B-4. The core breeding area for each of these species is well outside of the study area.

In conclusion, the avian fauna of the study area is rich and contains a number of species with interior forest requirements for successful breeding. Large tracts of intact forest are rare in the eastern United States due to a number of land use change associated reasons. Mountaintop mining in the study area has the potential to impact as much as 380,547 ac of forest. These impacts would result in fragmentation of the environment into areas of forests and grasslands. The remaining forest patches may provide proper habitat to maintain the population of most of the states avian fauna; however, a few species may be put into peril because their core breeding area is within the heart of the future mountaintop mining area. Loss of these species has more ecological importance than providing habitat for grassland species considered rare in the state because it suggests possible future endangerment of some forest interior species as opposed to the potential gain of some disjunct grassland species populations.

Impacts on Terrestrial Salamander Populations

Salamanders are an important ecological component in the mesic forests of the study area and are often the most abundant group of vertebrates in both biomass and number (Burton and Lykens, 1975; Hairston, 1987). Ecologically, salamanders are intimately associated with forest ecosystems acting as predators of small invertebrates and serving as prey to larger predators (Pough et al., 1987). Studies conducted in Eastern forests suggest that timber harvesting is detrimental to salamander populations (Bennett et al., 1980; Pough et al, 1987; Ash, 1988; Petranka et al., 1999). Specifically, Ash (1988) reported on the local extinction of Jordan's salamander (*Plethodon jordani*) from clearcut plots in North Carolina. Similarly, Petranka et al. (1993) found that forest floor salamanders were more than twice as abundant in mature forests as in clearcut plots.

Clearcutting occurs prior to surface coal mining; therefore, studies described above suggesting that timber harvesting is detrimental to salamander populations would seem to be applicable to the impact from mountaintop mining. No studies could be found that specifically address the impact of mountaintop mining on salamander populations. There are, however, many studies that present the negative impact that acidification of the terrestrial environment, a phenomenon associated with surface mining (Thomas et al., 2001 and references within), has on salamander populations (Dunson et al., 1992, Wyman and Jancola, 1992; Horne and Dunson, 1994; Frisbie and Wyman, 1995). One of the greatest impacts that mountaintop mining operations have on the terrestrial salamanders of the study area is the placement of fill in the valleys. This leads to the direct loss of salamanders under the fill and to a change in habitat on top of the fill. Removal of forests and the establishment of grasslands in once forested areas also leads to a decline in salamander populations. It has been suggested that forest clearing (clearcutting) degrades the forest floor microhabitat by increasing exposure to solar radiation and thus decreasing surface soil moisture thereby rendering it inhospitable to salamanders (Ash, 1988). This thesis has been supported within the study area. Handel (2001) reports that soil moisture within remnant forests was significantly higher than that of nearby reclaimed mine sites. Furthermore, Wood and Edwards (2001) observed a shift in the herpetofauna community from amphibian dominated in the forests to reptile dominated in grasslands of mine sites.

Petranka et al. (1993) estimates that between 75% and 80% of terrestrial salamanders are lost following clearcutting of mature timber stands. Furthermore, reestablishment of salamander populations to pre-harvest conditions has been estimated to range between 20 and 70 years (Petranka et al., 1993; deMaynadier and Hunter, 1995; Ash, 1997). Although these numbers differ and there is debate in the scientific community over which is correct (Petranka, 1999), it can be concluded that salamander populations suffer major setbacks in the years following forest removal. There is evidence that terrestrial salamander populations do not become successfully established in nearby forests as forest clearing is taking place (Hairston, 1987). Therefore, it can be concluded that salamander populations become reestablished once forests become reestablished.

Handel (personal communication) suggested, based on the findings of his study of reforestation on mined sites, that mined sites may take as long as 120 years or more to attain mature forest conditions. From this, we can conclude that salamander populations in the study will be reduced in number and biomass for a long period of time. This reduction in salamander populations may have negative impacts on the species that depend upon them in the food web.

Thirty-one (31) species of salamanders are known from the West Virginia portion of the study area (WV Gap data). Of these 25 species are known to inhabit the mixed mesophytic hardwood forest while 21 species are known to occupy cove hardwood forests. Petranka (1993) presented a conservative estimate that there are about 4,050 salamanders per acre of mature forest floor in Eastern forests (10,000/ha). Applying this number to the 11,231,622 acre of forest in the study area yields a conservative estimate of 36,390,455,280 salamanders in the study area. Assuming that 80% (Petranka, 1993) of the salamanders are lost in the projected forest impact areas, approximately 1,232,972,280 have the potential of being adversely impacted. This equates to 3.4% of the entire salamander population of the four-state study area. Species that are most likely to be affected are those that are most abundant on the forest floor and along the riparian areas of the small headwater streams. These are predominantly the *Plethodon* and *Desmognathus* species.

2. Discussion of Habitat Changes and Interpretation of Significance

Habitat changes will occur in the study area and these changes will involve a shift from a forest dominated landscape to a fragmented landscape with considerably more mining lands and eventually grassland habitat (Figure V.B-5). This shift should lead to a shift in the floral and faunal components of the ecosystem. For example, dry grassland species will dominate the once post-mined and forest harvested sites. This will result in an overall reduction in the native woody flora as well as a reduction in the spring herbs and other vegetative components characteristic to the study area (Handel, 2001).

Wildlife shifts will include a shift from forest to grassland species. The abundance of grassland birds will likely increase while many forest interior, neotropical migrant species will suffer losses in terms of number (Wood and Edwards, 2001). There will likely be an increase in game species such as whitetail deer and turkey due to an increase in grasslands and the diversification of the habitats. The herpetofauna will likely undergo a shift from mesic favoring salamander dominated communities along the riparian corridors of the small headwater streams and in the litter of the forest floor to a snake dominated grassland fauna (Wood and Edwards, 2001).

3. Potentially Adverse Impact on Biodiversity

Biodiversity is the variety of organisms in an area. In this case, the area is defined as the four-state study area; however, a better ecological boundary would be the Ecological Subregions described in Table II.A-1. Biodiversity can be applied to various levels of biological organization but in the case of assessing potential adverse impacts to biodiversity within the Ecological Subregions of the study area only two levels of biological organization apply. Impacts to the terrestrial environment may affect biodiversity of the at the (1) genetic and/or (2) species/population level. Species affected by fragmentation within the Ecological Subregions would include those with specific requirements for habitats that are lost and those with poor dispersal abilities.

The direct loss of habitat and fragmentation of a once contiguous environment is considered by some to be the most serious threat to biological diversity (Wilcox and Murphy, 1985). Unfortunately, the result of anthropogenic changes on the natural environment takes time, which makes impacts difficult to measure. The effects of habitat losses are likely to take generations, even centuries, before fully realized (Tilman et al., 1994; Brown and Lomolino, 1998).

Wilcove (1987), recognizing this time lag affect on natural environments, presented a series of sequential stages that are expected to occur following anthropogenic change to the natural environment. These stages lead finally to biological collapse and begin immediately following fragmentation of the natural environment.

1. Initial exclusion of some species when fragmented patches do not, by chance, include any individuals of the species.
2. Extirpation due to a loss of resources. Many species require multiple habitats for forage, shelter, and breeding purposes and some of the isolated patches in the fragmented environment may not include all the needs of each species.
3. Small population problems such as a reduced gene pool, unbalanced population demographics, and susceptibility to stochastic events (fire, severe weather, etc.).
4. Isolation effects like reduced gene flow and the increased frequency of deleterious genes in the population.
5. Ecological imbalances associated with predator-prey relationships, host-parasite relationships, and mutualisms. Furthermore, the fragmentation may lead to an increase in invasive species, which could further help trigger local extinctions. This stage may also include changes in the composition of the ecological communities, where populations once low number become dominant and visa-versa.

Thus, we can conclude that fragmentation of the study area has the potential to impose considerable impact on the terrestrial environment. Some of these impacts may be recognized immediately while others may take tens or hundreds of years to surface.

4. Carbon sequestration and the Forest Carbon Cycle

Energy flows and materials circulate through the global ecosystem. Essential nutrients and other chemicals, including man-made materials, flow from the non living to the living parts of the global ecosystem in a path know as the biogeochemical cycle.

The energy flow in terrestrial ecosystems depends on interactions between a number of biogeochemical cycles such as the carbon cycle and hydrological cycles. Terrestrial ecosystems play a role in the global carbon cycle. Carbon is exchanged between trees and the atmosphere through photosynthesis and respiration. The cycling of carbon as carbon dioxide involves assimilation and respiration by plants. Human activities affect the global carbon cycle. According to the Intergovernmental Panel on Climate Change, from 1850 to 1998, approximately 270 GtC has been emitted as carbon dioxide into the atmosphere from fossil fuel burning and cement production (IPCC, 2001).

Carbon dioxide is what is known as a greenhouse gas which means that it contributes to global warming. According to the World Resource Institute (1997), drawing carbon dioxide out of the atmosphere (sequestration) and into biomass is the only known practical way to remove large volumes of this greenhouse gas from the atmosphere (June 2001). Reforestation could potentially achieve significant carbon sequestration. It has been estimated that temperate forests sequester 1.5 to 4.5 tons of carbon per hectare per year as reported by the Intergovernmental Panel on Climate Change (2000).

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